ST. MARYS RIVER

REMEDIAL ACTION PLAN

The St. Marys River Area of Concern

Environmental Conditions and Problem Definitions

STAGE 1

Remedial Action Plan
Plan d'Assainissement

Canada Ontario

DNR

The St. Marys River Area of Concern

Environmental Conditions and Problem Definitions

Remedial Action Plan
Stage I

March, 1992

Ontario Ministry of the Environment, Detroit / St. Clair / St. Marys River Project
242A Indian Road, South, Room 203, Sarnia, Ontario N7T 3W4

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FORWARD

This document provides a summary of the environmental conditions in the St. Marys River Area of Concern (AoC) in Ontario and Michigan. It represents the Stage I submission of the St. Marys River Remedial Action Plan (RAP), in accordance with the Canada-U.S. Great Lakes Water Quality Agreement and the Canada-Ontario Agreement respecting Great Lakes Water Quality. It identifies many of the sources of contaminants which may contribute to the impairment of beneficial uses.

The report contains an executive summary which is presented as Chapter 1. Impairments to beneficial uses are summarized in Table 1.1. The identification of impairments is based on water, sediment and biota surveys which were carried out primarily in the 1984 to 1986 period including some available data as recent as 1990. The status of each beneficial use category has been assigned by the St. Marys River RAP Team, in consultation with the Binational Public Advisory Council (BPAC), using the Listing/Delisting Guidelines prepared by the International Joint Commission (IJC) in conjunction with applicable standards, guidelines and objectives where available.

Five municipal and industrial points sources discharging to the St. Marys River have been identified. Several non-point sources of contaminants are also identified. Available loadings data are presented for the major point and non-point sources. The most recent loadings data which have been utilized are based on sampling undertaken from 1986-1990 (point sources) and 1986 (non-point). Recent 1989 and 1990 data for those parameters which are regularly monitored at all municipal and industrial facilities in Ontario and Michigan have been utilized. Data from Ontario's Municipal-Industrial Strategy for Abatement (MISA) monitoring studies (1986-1988) of the iron & steel and pulp & paper sectors have also been utilized.

Results of several recent studies will assist in updating the problem definition. These include:

- 1989/90 point source data for the Iron and Steel and Pulp and Paper sectors collected under Ontario's MISA program;
- The Algoma Steel Slag Disposal Site Investigation (1987-1989) which indicates contaminants, loads and pathways from the slag site to the St. Marys River;
- The results of Environment Canada's pilot site initiative (1991) for the *in situ* treatment of contaminated sediments.

A number of data gaps have also been highlighted. These include:

- Additional information on ambient conditions within the AoC with which to make definitive conclusions regarding the impairment status for the tainting of fish and wildlife flavour, the extent of eutrophication in embayments, and the degradation of phytoplankton and zooplankton communities in embayments;
- The quantification of non-point sources including CSOs, stormwater and atmospheric inputs;
- Loadings data for Michigan tributaries.

More recent point source loadings data collected under Ontario's MISA program will be updated to Stage I as an initial component of the Stage II process. This process will also identify and prioritize site specific studies required to fill other data gaps.

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1 EXECUTIVE SUMMARY

1.1 INTRODUCTION

The St. Marys River was identified in 1985 by the International Joint Commission (IJC) as one of 42 Areas of Concern (AoC) in the Great Lakes Basin. Areas of Concern were identified based on known impairments of beneficial water uses. The St. Marys River was identified as an AoC as a result of problems associated with phosphorus, bacteria, heavy metals, trace organics, contaminated sediments, fish consumption advisories and impacted biota.

The river is an international waterway forming a portion of the boundary between Canada and the United States. This Remedial Action Plan (RAP) is thus being developed as a binational effort. In December of 1985 an agreement was signed by Governor James Blanchard of Michigan and Premier David Peterson of Ontario, formally establishing a joint RAP process and identifying Ontario as having the lead role for development of the St. Mary River RAP. The first step in the process was the formation, in 1987, of a Binational Remedial Action Plan Committee, or RAP Team, comprised of representatives from the Ontario Ministries of the Environment and Natural Resources, the Michigan Department of Natural Resources, U.S. EPA and Environment Canada.

The RAP Team has been charged with the development of a Remedial Action Plan for the St. Marys River, which is a staged process. This document is the first of three stages. Stage I is being prepared in order to define the problem, addressing the following requirements:

- detail existing environmental conditions in order that environmental problems in the St. Marys River may be defined and described;
- identify beneficial uses that are impaired, the degree of impairment and the geographical extent of impairment within the Area of Concern; and
- define the causes of impairment, providing an assessment of all known sources of pollutants and a description of other potential sources.

In addition to the technical document to address the above, an extensive public participation program has been developed in order to inform the public, improve the plan by gaining information and advice from the public, gain support for plan implementation, and provide a mechanism for accountability to the public.

A number of initiatives were undertaken to raise the profile of the RAP process among the general public through outreach activities. In particular, effort was focused on the establishment of a Binational Public Advisory Committee (BPAC) which could work with and advise the RAP Team on a regular basis during development of the RAP. The BPAC was created during the summer and fall of 1988. Its specific roles are to inform the RAP Team about public opinion and views regarding goals for the RAP and to assist with water use goals, problem identification, planning methodology, technical data, preferred remedial options, plan recommendations and plan adoption.

The BPAC consists of 42 charter members, with equal representation from both Ontario and Michigan. Members represent a cross-section of communities and interest groups on both sides of the river. They have demonstrated extensive interest and knowledge during the development of the RAP and have provided active and informed input throughout the process. The BPAC elected four of its members as delegates to the RAP Team in order to better facilitate communication.

Agency members of the RAP Team are able to provide technical expertise, either directly or through communications with experts within each of their organizations. While the Ontario Ministry of the Environment has been charged with the lead responsibility for development of the St. Marys River RAP, the Michigan Department of Natural Resources co-chairs the RAP Team. Additional members represent the

Ontario Ministry of Natural Resources, Environment Canada, Fisheries and Oceans Canada, and the U.S. Environmental Protection Agency.

1.2 THE RAP PROCESS

The mechanisms for a cooperative binational venture such as a Remedial Action Plan for the St. Marys River have been established through the development of the Great Lakes Water Quality Agreement (GLWQA). This agreement, first signed by Canadian and U.S. governments in 1972, was revised in 1978 and subsequently amended in 1987. The amending protocol in 1987 included an annex which required Canadian and U.S. governments to develop and implement remedial action plans for each of the Great Lakes Areas of Concern. As outlined in the 1987 GLWQA, an Area of Concern is defined as "a geographic area that fails to meet the General or Specific Objectives of the Agreement where such failure has caused or is likely to cause impairment of beneficial use or the area's ability to support aquatic life". Fourteen use impairments are specified in the GLWQA:

i. Restrictions on fish and wildlife consumption;
ii. Tainting of fish and wildlife flavour;
iii. Degradation of fish and wildlife populations;
iv. Fish tumours or other deformities;
v. Bird or animal deformities or reproductive problems;
vi. Degradation of benthos;
vii. Restrictions on dredging activities;
viii. Eutrophication or undesirable algae;
ix. Restrictions on drinking water consumption, or taste and odour problems;
x. Beach closings;
xi. Degradation of aesthetics;
xii. Added cost to agriculture or industry;
xiii. Degradation of phytoplankton and zooplankton populations; and
xiv. Loss of fish and wildlife habitat.

The impairment of any one of these beneficial uses could be sufficient to list an area as an Area of Concern. Using this list as a basis, the IJC has solicited input in the development and refinement of Listing/Delisting Criteria for Great Lakes AoC. In some cases, even with specific criteria outlined, it is difficult to definitively establish whether a beneficial use is impaired. As a consequence, the RAP Team has been required to consult with both technical experts within and outside the RAP Team, as well as with the BPAC, and to exercise judgement. The St. Marys River Remedial Action Plan has used available environmental quality data to compare with the IJC Listing Criteria, in order to determine the impairment status of beneficial uses in the St. Marys River. In addition, violations of existing water quality criteria or effluent requirements have been highlighted even though a direct relationship with an impairment of beneficial uses may not be demonstrated. The public (both individuals and organizations) and various levels and types of government agencies were included throughout the Stage I RAP development process in an attempt to reach consensus on the problems in the St. Marys River.

Annex 2 of the 1987 protocol amending the GLWQA specifies that the RAP should be submitted to the IJC for review and comment at 3 stages. This document represents a completed Stage I outlining the definition and description of environmental problems, causes of these use impairments, a description of all known sources of pollutants involved, and an evaluation of other possible sources.

Stage II will define the specific goals for the Area of Concern and will describe the remedial and regulatory measures selected to restore beneficial water uses. The Stage II RAP will include:

1. an evaluation of remedial measures in place;

2. an evaluation of alternative additional measures to restore beneficial uses and associated costs;

3. selection of additional remedial measures required to restore beneficial uses and a schedule for their implementation; and

4. an identification of the persons, agencies, or organizations responsible for implementation of the selected remedial measures.

Stage III of the St. Marys River RAP will be submitted when monitoring indicates that identified beneficial uses are restored. This stage of the RAP will include:

1. a process for evaluating the remedial measures implementation and effectiveness; and

2. a description of surveillance and monitoring programs designed to track the effectiveness of remedial measures, and the eventual confirmation of the restoration of the uses.

1.3 CONTROL PROGRAMS

Numerous programs, regulations, objectives, guidelines and agreements to maintain and enhance environmental quality are in place and/or under development in Ontario, Michigan and at the federal levels in both Canada and the United States. The Stage I RAP identifies the current regulatory tools available to each jurisdiction and the control mechanisms currently in place and under development. An evaluation of existing control criteria with regards to environmental conditions provides additional focus for identifying impaired beneficial uses. It will provide useful direction in the development of Stage II and beyond in assessing the need for additional control in order to achieve the restoration of beneficial uses.

1.4 DESCRIPTION OF THE STUDY AREA

The St. Marys River Area of Concern includes the area of the river which extends from Whitefish Bay at an imaginary line drawn between Point Iroquois, Michigan and Gros Cap, Ontario downstream to Quebec Bay, Ontario - Humbug Point, Ontario in the St. Joseph Channel and Hay Point, Ontario - Point aux Frenes, Michigan in the West Neebish Channel (Figure 1.1).

The St. Marys River is the outlet of Lake Superior from Whitefish Bay. It flows southeasterly through several channels to Lake Huron, a distance of 100 to 120 km (63 to 75 miles) depending on which route is taken. The elevation of the river drops a total of 6.7 m (22 feet) over this distance, with 6.1 m (20 feet) occurring at the St. Marys Rapids. The average flow volume of the St. Marys River at Sault Ste. Marie, over a period of 124 years, was 2,144 m^3/s (75.8×10^3 cf/s).

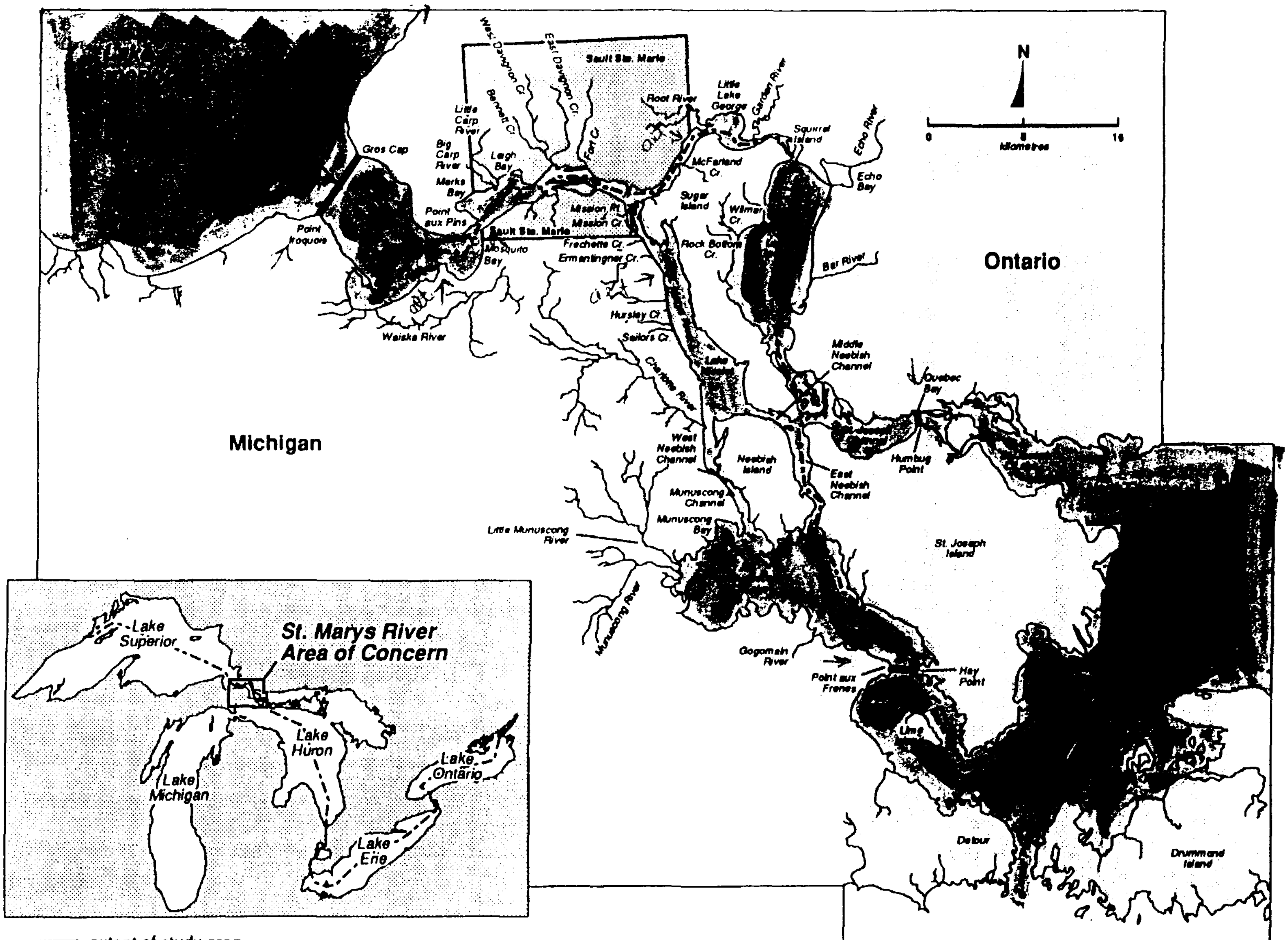
Extensive alterations to the St. Marys River at the rapids have been undertaken since the mid 1800's in order to facilitate ship navigation between Lakes Huron and Superior, enhance rail and vehicular traffic, and provide hydroelectric power.

Figure 1.1

St. Marys River Remedial Action Plan

Location map of the St. Marys River Area of Concern

(after UGLCCS 1988)



extent of study area

The watershed of the St. Marys River includes all of the Lake Superior drainage basin as well as a number of small tributaries which drain directly into the river. Michigan tributaries include the Waiska, Charlotte, Little Munuscong, Munuscong and Gogomain Rivers as well as several small streams. In Ontario, the main tributaries are the Big Carp, Little Carp, Root, Garden, Echo and Bar Rivers and Bennett, East Davignon, West Davignon and Fort Creeks.

Several islands have been formed when the river divided into its numerous channels. Sugar Island is the largest upstream island and separates Lake George (east) and Lake Nicolet (west). Both lakes are broad expanses of the river which empty into downstream channels around St. Joseph and Neebish Islands. Between Sugar and Neebish Islands is the Middle Neebish Channel; the West Neebish Channel separates Neebish Island from the Michigan mainland. St. Joseph Island is separated from Neebish Island by the Munuscong Channel and from the Ontario mainland by the St. Joseph Channel.

The St. Marys River lies at the junction between the igneous and metamorphic rocks of the Precambrian Shield to the north and the sedimentary strata formed during the Ordovician and Silurian Periods to the south. These are overlain by glacial deposits including ground moraines, shallow till, end moraines and outwash. These in turn have been modified by glacial lake action, resulting in the deposition of lacustrine clays and silts which cover large portions of the study area. The lake deposits appear as flat to gently rolling plains in Michigan and immediately adjacent to the river in Ontario. To the north these plains give way to the rugged bedrock-controlled topography of the Canadian Shield. Soils consist of fine-textured clays and silt loams with pockets of organic material formed on the plains of Michigan and adjacent to the river in Ontario; well-drained sands characteristic of the till deposits located north and west of Sault Ste. Marie, Ontario; and extremely well-drained outwash sands and gravels at the mouth of the Garden River.

The vegetative communities of the AoC include several upland and lowland types. Upland hardwood forests of the Great Lakes-St. Lawrence Forest Region (sugar maple, yellow birch and red oak) occur along the river and adjacent to Lake Superior. Mixed hardwood-conifer Boreal forests (white spruce and poplar) occur in more northerly portions of the AoC. Wet, forested sites consist of black spruce, tamarack and white cedar or black ash. Non-forested wetlands include thicket swamps, sedge and grass meadows, and marshes consisting of cattails and various rushes. Extensive areas of emergent marsh wetlands border the lower river. Chippewa County, Michigan, for example, has 4,848 ha (11,979.4 acres) of coastal wetlands. Wetlands are particularly important as habitat for fish, waterfowl and other wildlife.

1.5 LAND USE

Approximately 83 percent of the lands within 5 km (3 miles) of the St. Marys River consist of undeveloped forest and wetlands. The remainder is used for a mix of agriculture, urban and rural residential, industry, commercial, and waste disposal.

Agriculture is the second most widespread land use, with about 10 percent of the area in farmland. Generally, agriculture is restricted due to a limited growing season and poorly drained soils. Livestock for dairy and meat products and hay crops are by far the dominant agricultural activities.

Urban areas constitute about 5 percent of the area. The largest communities include the cities of Sault Ste. Marie, Ontario with a population of 85,000 and Sault Ste. Marie, Michigan with 15,000 residents. These communities serve as the industrial and commercial centres for a large portion of northern Michigan and the Algoma region of Ontario. The Ontario communities also include Echo Bay and two Indian Reserves (Rankin Location and Garden River).

Industry consists of two dominant activities, steel making (Algoma Steel) and paper products (St. Marys Paper). Both are located in Sault Ste. Marie, Ontario. Small secondary manufacturing industries serve as support industries to the major steel and paper producing companies. Sand and gravel extraction for transportation and construction is also an important commercial activity on the Ontario side of the river.

A further land use in the St. Marys River AoC includes waste disposal. In Michigan, there are three municipal and four industrial waste sites. The municipal sites include the Dafter, Bay Mills and Superior Sanitation-Rudyard landfills. The Dafter landfill is currently the only active site. Bay Mills was closed in mid 1991 and Rudyard was closed in early 1990. The Anderson Corporation has purchased the Rudyard site and installed monitoring wells and a new leachate collection system in order to reopen the site. Both the Dafter and Bay Mills sites have monitoring wells for the detection of groundwater contamination. Three industrial sites, Cannelton Industries, Union Carbide and the Superior Sanitation 3 mile site and all are on Michigan's Priority List for Evaluation and Interim Response (Act 307 List). The Soo Line Railroad waste site contains mostly construction and demolition debris. The Algoma Steel Slag Dump and City of Sault Ste. Marie Cherokee Landfill are the two waste sites in Ontario. The slag dump forms a portion of the shore of the river, immediately west of Algoma Steel. Investigations have identified the presence of numerous contaminants in groundwater within the slag. The Cherokee landfill is undergoing expansion and the installation of a leachate collection system.

1.6 WATER RESOURCE USE

Water uses on the St. Marys River are numerous and include the following: shipping, domestic and industrial water supply, hydroelectric power generation, fish and wildlife habitat, sport fishing, hunting and trapping, fishing and hunting by native people, recreational activities, and effluent receiver.

The St. Marys River is part of the Great Lakes Seaway and the steel industry in Sault Ste. Marie requires coal and lignite from lower Great Lakes ports or ocean ports and iron ore and limestone from ports in the upper Great Lakes. Grain is also shipped through the river from Thunder Bay to the lower Great Lakes and overseas. A minimum depth of 8.3 m (27 feet) is required for shipping, necessitating the periodic dredging of sediments. Dredge spoils from navigation channels are uncontaminated and have always been approved for open water disposal. Dredge spoils from the Algoma slip are placed in upland facilities.

The river is the source of drinking water for over 96,000 people. Municipal intakes are located in the upper river at Big Point, Michigan and at Gros Cap, Ontario. There are also numerous communal and private intakes along the river serving permanent and seasonal residences which are not connected to municipal supplies. Water is also withdrawn for cooling and process streams at Algoma Steel and St. Marys Paper. Hydroelectric generating stations in Ontario and Michigan also utilize the St. Marys River.

The St. Marys River provides a diverse and extensive fish and wildlife habitat. There are four distinct fish habitat types including open waters and embayments; emergent wetlands; sand-gravel beaches; and the St. Marys Rapids. Seventy-four species of fish are known to occur in the river with at least 44 species utilizing the wetland communities for spawning, nursing and feeding. Some common species include trout-perch, several varieties of minnow and shiner, yellow perch, walleye, black crappie, rock bass, smallmouth bass, white sucker, brown bullhead, lake herring, lake whitefish, pink salmon, northern pike and alewife. There are also over 180 species of waterfowl, colonial waterbirds, shorebirds, passerines and raptors which utilize the river and its immediate environs. Characteristic species include mallard, mergansers, black ducks, Canada geese, common goldeneye, blue-winged teal, common loon, ring-billed gull, common and black terns, cormorant, great blue heron, bald eagle, osprey, snowy and great grey owls, and peregrine and gyrfalcon. The most common large mammal is the white-tailed deer. Small mammals include beaver, otter, muskrat, mink, raccoon, American water shrew and northern water shrew.

Commercial fishing by native peoples is only permitted in the upper reach of the St. Marys River. Lake whitefish and lake trout in eastern Lake Superior and upper reach of the St. Marys River and lake whitefish plus walleye in the North Channel of Lake Huron are the primary species and locations of commercial fishing activities. Native subsistence fishing for personal and family use is permitted in the St. Marys River. Aggregate extraction from Whitefish Bay in Lake Superior is an identified resource use conflict, as this area also supports important whitefish spawning grounds. Stocks of lake whitefish have been depleted in the lower river since the 1930's.

Sport fishing has been a popular long-standing activity on the St. Marys River, averaging approximately 154,799 (±27,723) angler days per year. The catch per unit effort has declined from approximately 1.5 fish/angler-hour in the 1930's to about 0.5 during the 1970's. The species most sought-after are lake whitefish, yellow perch, northern pike and brown trout in the upper river; Pacific salmon, pink salmon, rainbow trout, brook trout, brown trout, walleye, whitefish and white sucker at the St. Marys Rapids; and northern pike, yellow perch, walleye, smallmouth bass and panfishes in the lower river. The St. Marys River sport fishery is estimated to be worth $2.5 million (U.S.) annually to Michigan anglers. The river and area fishery has an estimated economic value of between $15 and $20 million (Canadian) annually to Sault Ste. Marie, Ontario.

Hunting and trapping are significant uses of the St. Marys River Area of Concern. Mallards, ring-necked ducks, scaups, white-tailed deer, black bear, moose (Ontario only), ruffed grouse and snowshoe hare are the principal species hunted. Species most commonly trapped include beaver, mink, muskrat and otter. Martin, fisher and lynx are trapped in Ontario but are protected in Michigan.

The St. Marys River is a popular resource for recreational activities including power boating, sailing, yachting and houseboating. There are seven marinas located between Bruce Mines and Sault Ste. Marie, Ontario. Other recreational activities include waterskiing, windsurfing, skating, cross-country skiing, snowmobiling, hiking, picnicking and nature appreciation.

Wastewaters from three municipal wastewater treatment plants and two industries are discharged to the river. The Sault Ste. Marie, Michigan Wastewater Treatment Plant (WWTP) services a population of 15,000. It has an average daily flow of 11.3 x 10^3 m^3/d (3 MGD) receiving wastewater from residential and commercial users. Sault Ste. Marie, Ontario has two Water Pollution Control Plants (WPCP) known as the East End and West End WPCPs. Average daily flows for these two plants during 1988 were 34.2 x 10^3 m^3 (9 MG) and 7.7 x 10^3 m^3 (2 MG), respectively. The East End facility serves a population of 52,000 with residential, commercial and light-industrial users. The West End WPCP is the newest of the facilities serving a population of 17,500 residential and light-industrial users.

St. Marys Paper is a groundwood pulp and paper mill which produces 106,000 tonnes/year of paper. This facility discharges 23.7 x 10^3 m^3/day (6.3 MGD) of treated wastes. Algoma Steel Corporation, during 1989, produced 2.53 x 10^6 m^3/day tonnes of raw steel and discharged an average of 486 x 10^3 m^3/day (128 MGD) of treated wastes to the river. Production at this facility has since decreased significantly due to a strike and poor economic conditions. The Algoma Steel Tube Mill and Cold Mill effluent discharges to East Davignon Creek, which flows into the St. Marys River.

Non-point sources of contaminants to the river include atmospheric deposition onto the watershed, urban and rural runoff, storm sewers, combined sewer overflows, the resuspension of contaminated sediments, groundwater, and spills from ships and industries.

1.7 ENVIRONMENTAL CONDITIONS

1.7.1 Water Quality

Long term monitoring of St. Marys River water quality reveal that contaminants associated with industrial and municipal sources have declined from the mid 1960's. Concentrations of phenols, ammonia, cyanide and certain heavy metals have declined from a high in mid 1960 downstream of Sault Ste. Marie, Ontario point sources. This trend is attributed to reduced loadings from major point sources including Algoma Steel, St. Marys Paper and the Sault Ste. Marie, Ontario East End WPCP, as well as to increased water flow since 1982 resulting from increased diversion to the Clerque Generating Station.

Transboundary contamination by phenols from Ontario to Michigan occurs in the Lake George Channel.

Water quality in and downstream of the Algoma Slip is impaired, based on exceedences of OMOE, MWQS and GLWQA objectives for dissolved oxygen, turbidity, total phenols, total and unionized ammonia, iron and total phosphorus. 1986/87 sampling indicates that free cyanide levels were below the PWQO and MWQS. Total polycyclic aromatic hydrocarbon (PAH) concentrations exceed the U.S. EPA Ambient Water Quality Criteria (AWQC) for Human Health Criteria for fish consumption (31 ng/L) (31 ppt) in the Algoma Slip and downstream from the Algoma Slag Site to the East End WPCP. Concentrations of PAHs along the Michigan shoreline are similar to background, indicating no transboundary or localized inputs.

Total phosphorus, unionized ammonia and fecal coliforms exceeded PWQO downstream of the East End WPCP in 1989.

Fecal coliform bacteria occur in densities which exceed the Provincial Water Quality Objective and Michigan Water Quality Standard immediately downstream of storm sewers, industrial outfalls and the East End WPCP. Exceedences of applicable objectives for fecal coliforms also occur downstream of the Sault Edison Power Canal as a result of combined sewer overflows. Exceedences of fecal coliforms occurred downstream of East End WPCP as far as Bells Point (Little Lake George).

1.7.2 Bottom Sediment Quality

Sediment cores from Lake George indicate that the concentrations of total PAHs, total PCBs, DDT, zinc, chromium, lead and oil and grease peaked in the 1960's and 1970's but have since declined. The areal extent of sediment contamination by zinc and oil and grease along the Sault Ste. Marie, Ontario shoreline has also decreased from 1973 to 1983.

Contaminants in sediments from the Algoma Slip exceed the most stringent Ontario OWDG or "moderately polluted" U.S. EPA guidelines for dredged materials. These contaminants include iron, zinc, cyanide and oil and grease. In addition, total PAHs exceeded the proposed Ontario Sediment Quality Guideline of 2.0 mg/kg.

Sediments downstream of the Algoma Slip and along the Ontario shore, in Little Lake George and Lake George exceeded guidelines for dredged materials (OWDG and U.S. EPA) for iron, chromium, zinc, lead, arsenic, manganese, nickel, copper, oil and grease, PCBs, LOI, total phosphorus and TKN. Total PAHs exceeded the proposed Ontario Sediment Quality Guideline at these locations.

Lake Nicolet exceedences included iron, chromium, zinc, lead, arsenic, manganese, nickel, copper, cadmium, oil and grease, PCBs, LOI, total phosphorus, and TKN. Chromium, nickel, copper, mercury (one sample), and PCBs were exceeded in Munuscong Lake. Chromium and cadmium exceedences occur at the head of the St. Marys River along the Michigan shore at the Cannelton Industries waste disposal site.

1.7.3 Biota Quality

Phytoplankton composition, low algal densities and low chlorophyll *a* concentrations indicate that the upper reaches of the St. Marys River reflect the oligotrophic nature of Lake Superior.

The benthic macroinvertebrate community of the river is diverse with over 300 taxa recorded.

Industrial and municipal discharges severely impact the benthic community in the vicinity of the Algoma Slip and in embayments on the Ontario side, downstream of the Rapids. Moderate impairment occurs within a 500 m (1,640 feet) wide area extending 4 km (2.5 miles) along the Ontario shore downstream of the industrial discharges (Algoma's Terminal Basins discharge). Recovery of the benthic community was observed to begin 5 km (3.1 miles) downstream of the Terminal Basins discharge, with complete recovery at 24 km (15 miles), in the lower section of Lake George.

Reduced contaminant loadings from industrial facilities in recent years has not, however, resulted in improvements in the rivers benthic communities. Visible oily residues in sediments continue to be associated with reduced numbers or the absence of burrowing mayflies (*Hexagenia limbata*). The presence of high concentrations of oil, cyanide and heavy metals markedly depresses the production of burrowing mayflies (*Hexagenia limbata*). There was, however, no significant relationship between heavy metal and organic concentrations in sediments and concentrations in tissues of associated benthic organisms. Uncontaminated mussels exposed to river water near and downstream of Ontario discharges accumulated significantly higher levels of certain PAH compounds than mussels introduced in the river upstream of discharges. Accumulations along the Michigan shore were generally at lower levels than along the Ontario shore.

Organochlorine contaminant levels in juvenile fish from Ontario waters of the St. Marys River are below permissable GLWQA concentrations for the protection of fish-eating birds and animals. In whole adult fish homogenates from the St. Marys and Tahquamenon Rivers, only PCB levels were above the GLWQA objective for the protection of birds and animals which consume fish. The larger size classes of white sucker, walleye, northern pike and lake trout in Ontario waters currently have a consumption advisory for humans due to mercury contamination (in dorsal fillets). Because of PCBs in Lake Huron fish, the Michigan advisory applies to migratory fish from the Lake.

Contaminant levels in dorsal fillets of adult sport fish (1986, 1987 and 1989) from Ontario and Michigan waters in the St. Marys River are similar and, except for mercury, below applicable Health and Welfare Canada guidelines and Michigan Department of Public Health trigger levels. Levels of mercury exceeded both the Canadian and MDPH guideline and trigger level (0.5 mg/kg) in fish captured in Ontario waters downstream of the Rapids and in Michigan waters in Munuscong Lake. As a result, the Ontario government has issued restricted consumption advisories for larger sizes of longnose sucker, white sucker, walleye, northern pike and lake trout. The MDPH has issued a consumption advisory for walleyes larger than 48 cm (19 inches).

There are limited data on contaminant concentrations in birds or mammals of the St. Marys River AoC. Evidence to date suggests that concentrations of PCBs, p,p'-DDE and 2,3,7,8-TCDD in herring gull eggs from Lake George, while elevated, are typical of other areas of the Great Lakes including Lake Superior. The highest PCB concentration measured in common tern eggs from the lower river was in the range that could produce harmful effects in eggs. There have been neither deformities documented nor reproductive problems reported in the St. Marys River AoC.

The Canadian Wildlife Service conducted a study (fall 1988 to fall 1990) in order to identify and quantify the contaminants present in breast muscle of waterfowl from the St. Marys River. Concentrations of mercury in breast muscle ranged from 0.13 to 0.46 mg/kg with the highest values in common mergansers. Most pesticides and herbicides were either not detected or very low. Concentrations of aroclor were detected in all waterfowl sampled with values ranging from 0.002 to 4.873 mg/kg. Because there are no criterion for contaminants in birds the significance of these results is not known.

1.8 ENVIRONMENTAL CONCERNS/USE IMPAIRMENT

A determination as to whether a specific use impairment exists in the St. Marys River AoC was made using the Listing/Delisting Guidelines for Great Lakes Areas of Concern in conjunction with applicable standards, guidelines and objectives where available. In the absence of standards, guidelines or objectives, impairment status is based on best professional judgement from the evidence available. The status of beneficial uses as well as exceedences of ambient standards, guidelines and objectives are summarized in Table 1.1.

Table 1.1 Summary of Great Lakes Water Quality Agreement beneficial uses and their significance and impairment status with regard to the St. Marys River Area of Concern.

GLWQA Beneficial Use	Status	Significance to St. Marys River
Restrictions on Fish and Wildlife Consumption		
Restrictions on Fish Consumption	Impaired	Fish consumption advisories are currently in effect: **Ontario** mercury: larger sizes of longnose sucker, white sucker, walleye, northern pike and lake trout **Michigan** mercury: St. Marys River walleye in excess of 48 cm (19 inches) PCBs: restricted consumption of brown trout, lake trout and rainbow trout from Lake Huron and tributaries
Consumption of Wildlife		Although there are no guidelines for human consumption, OMNR has advised against the consumption of kidneys and liver from moose, black bear and deer because of high cadmium levels for the entire Province of Ontario.
Tainting of Fish and Wildlife Flavour	Requires assessment	Although there have been no confirmed reports of tainted fish flavour, phenol concentrations at levels which may cause tainting, have been detected. A comprehensive study is required to evaluate the status of this beneficial use.
Degradation of Fish and Wildlife Populations	Impaired	
Dynamics of Fish Populations		Large populations of sea lamprey are contributing to the mortality of large migratory fish such as salmon. 1986 through 1990 records indicate 40 - 60 lamprey wounds for every 100 salmon taken. Fish fauna are diverse and healthy however, populations of native fish have been reduced and assemblages have changed due to habitat alteration, overfishing, pollution and stocking.
Body burdens		Low levels of PCBs, chlordane, BHC and DDT have been found in juvenile yellow perch and spottail shiners. Adult fish contaminants include mercury, PCBs, and detectable levels of chlordane, DDT, BHC, nonachlors, dieldrin, pentachlorobenzene, hexachlorobenzene and octachlorostyrene. Effects of these chemicals on fish are not known.
Dynamics of Wildlife Populations		Wildlife populations appear to be stable or increasing (i.e. double-breasted cormorants) but assessment criteria is required. Common tern populations are decreasing while ring-billed gull populations increase due to a decline in nesting habitat.
Body burdens of Wildlife		Mercury concentrations in waterfowl breast meat ranged from 0.12 to 0.46; aroclor (PCBs), detected in all specimens, ranged from 0.002 to 4.873 mg/kg; however there is no criteria available for assessment.
Fish Tumours and Other Deformities	Impaired	Impaired due to the incidence of liver tumours in brown bullheads from Munuscong Bay. White suckers, captured downstream of the Rapids along the Ontario shore in 1987, showed siginificantly higer levels of mixed function oxidases (MFO) in their livers than did fish captured in Lake Superior. This is likely due to contaminants in the St. Marys River water, sediment and benthos.

Table 1.1 (Cont'd)

GLWQA Beneficial Use	Status	Significance to St. Marys River
Bird and Animal Deformities or Reproductive Problems	Not Impaired	Bird or animal deformities have not been found in the St. Marys River AoC nor have reproductive problems been reported.
Degradation of Benthos Dynamics of Benthic Populations	Impaired	Benthic community health is good on the Michigan side of the river. Benthic communities are moderately impaired on the Ontario side from the Algoma Slag Site downstream 4 km. Impairment also occurs on both sides of the Lake George Channel, within Little Lake George and the north end of Lake George.
Body burdens of Benthic Organisms		Arsenic, mercury and PCBs tend to bioaccumulate in benthic organisms. Caged mussels placed downstream of the Algoma Slip acquired the highest total PAH levels. Total PAH levels were low in mussels placed upstream of the Algoma Slip and near the Michigan shore. The effects of these contaminants on benthic organisms is not known.
Restrictions on Dredging Activities	Impaired	Contaminated dredge spoils from the Algoma Slip must be disposed of on an upland waste site. Dredge spoils from navigation channels have always been approved for open water disposal. Sediments from the following sites: downstream of the Algoma Slag Site along the Ontario shore; on both sides of the Lake George Channel; Little Lake George; the northern half of Lake George; the Michigan shore adjacent to the Cannelton Industries waste site; the head of the St. Joseph and West Neebish Channels; and Lake Munuscong had contaminant levels that exceeded OMOE guidelines or U.S.EPA guidelines for the disposal of contaminated sediment.
Eutrophication or Undesirable Algae	Impaired	Citizens have reported excessive amounts of algae in embayments and slow moving parts of the river downstream of the East End WPCP. Open waters of the St. Marys River reflect the oligotrophic (nutrient poor) character of Lake Superior waters. Conditions in embayments and slow moving areas of the river have not been documented.
Restrictions on Drinking Water Consumption or Taste and Odour Problems Consumption	Not Impaired	Treated water consumption from municipal sources has never been restricted however, ambient conditions in the water restrict consumption prior to treatment.
Taste and Odour Problems		Taste and odour problems have not been reported.
Ambient Water Quality	Impaired	Exceedence of ambient water quality criteria in the St. Marys River. Localized impairment. Exceedences of criteria for dissolved oxygen, turbidity, phenols, total and unionized ammonia, iron, total phosphorus, PAHs and bacteria occur downstream of Ontario discharges. Cyanide exceedences were not recorded in the 1986/87 OMOE survey.

Table 1.1 (Cont'd)

GLWQA Beneficial Use	Status	Significance to St. Marys River
Beach Closings and Body Contact	Impaired	In Michigan, total body contact activities are periodically impaired due to elevated bacteria levels. Bacterial densities have exceeded PWQO and MWQS.
Degradation of Aesthetics	Impaired	Oil slicks downstream of the Algoma Slip and Terminal Basin have occurred. Floating scums periodically occur along the north shore of Sugar Island, the Ontario shoreline of Lake George Channel and downstream. Oily fibrous material mixed with woody material periodically occur along the Ontario shoreline.
Added Cost to Agriculture and Industry	Not Impaired	None documented.
Degradation of Phytoplankton and Zooplankton Populations	Not Impaired in open water	Open water community structure and densities reflect Lake Superior. Communities in embayments and other slow-moving areas require further assessment because of impaired ambient water quality.
Loss of Fish and Wildlife Habitat	Impaired	Significant loss of fish and wildlife habitat have occurred as a result of shoreline alteration, industrialization, urbanization and shipping activities particularly in the St. Marys Rapids.

1.8.1 Restrictions on Fish and Wildlife Consumption

1.8.1.1 Restrictions on Fish Consumption

Fish consumption advisories are in effect due to contamination by mercury. For fish caught below the St. Marys Rapids, the Ontario (1991) recommended long term consumption limit is 0.2 kg/week (0.44 lbs/week) for longnose suckers of 30-45 cm (12-18 inches) in length, white suckers of 45-55 cm (18-22 inches), or walleye of 45-65 cm (18-26 inches). In Lake George, the limit is 0.2 kg/week (0.44 lbs/week) of northern pike of 65-75 cm (25-29 inches), lake trout of 55-65 cm (21-25 inches), or walleye of 45-55 cm (14-21). Consumption of walleye of 55-65 cm (21-26 inches) should be limited to 0.1 kg/week (0.22 lbs/week). Meals of northern pike over 75 cm (30 inches) from the St. Joseph Channel are limited to 0.2 kg/week (0.44 lbs/week). Children under 15 and women of childbearing age should not eat fish of these size classes.

In Michigan, restricted consumption of walleye in excess of 48 cm (19 inches) taken from Munuscong Bay is advised. Michigan consumption restrictions for Lake Huron also apply to its tributaries. Restricted consumption advisories have been issued for brown trout less than 53 cm (21 inches), lake trout and rainbow trout. A no consumption advisory has been issued for brown trout over 53 cm (21 inches). Consumption restrictions of not more than 1 meal/week have been recommended for walleye over 48 cm (19 inches). Nursing women, pregnant women, women intending to have children and children 15 years and under are advised to limit consumption to 1 meal/month.

1.8.1.2 Restrictions on Wildlife Consumption

Although there are no restrictions specific to the St. Marys AoC, the Ontario Ministry of Natural Resources has recommended that kidneys and liver of moose, black bear and deer not be consumed due to elevated cadmium concentrations. This advisory applies to animals taken anywhere in Ontario.

1.8.2 Tainting of Fish and Wildlife Flavour

The Michigan Department of Natural Resources has investigated incidental reports of tainting and has not found substantive evidence. A 1990 MDNR survey, conducted with local sport fishermen, reported no incidents of tainted fish. However, total phenol concentrations have exceeded PWQO (1986 and 1987) and may contribute to the tainting of fish flavour.

1.8.3 Degradation of Fish and Wildlife Populations

1.8.3.1 Dynamics of Fish Populations

The St. Marys River fishery has changed considerably over time. The increasing population of adult spawning sea lamprey in the St. Marys River suggests that sea lamprey are contributing to the increased mortality of fish, particularly salmon and lake trout in Lakes Huron and Superior. Migratory species such as salmon show a high incidence of wounds (40-60 wounds per 100 fish, 1986-1990). The St. Marys River has become a major spawning ground for sea lamprey and the chemical treatment of lamprey larvae will be difficult and expensive due to the rivers large size.

Although the sport fishery is generally healthy, populations of lake herring and lake whitefish in the lower river have decreased. In addition to sea lamprey increases, negative impacts to fish populations include overfishing, habitat loss and reduced populations and diversity of benthic fauna.

1.8.3.2 Body Burdens of Fish

Analysis of whole, young-of-the-year yellow perch and spottail shiners (which are routinely sampled to assist in pinpointing sources of contamination) have shown that levels of PCBs, chlordane, BHC, DDT and its metabolites, mirex, and chlorinated benzenes, aliphatics and phenols are either not detected or below the GLWQA objectives for the protection of birds and animals which consume fish (Section 6.7.1.2). PCBs in adult white sucker and carp from the St. Marys and Tahquamenon Rivers are above the GLWQA objective.

1.8.3.3 Dynamics of Wildlife Populations

There is no documentation indicating that wildlife populations have been impaired. It is likely that populations have been influenced by some habitat losses.

1.8.3.4 Body Burdens of Wildlife

Concentrations of mercury in waterfowl breast muscle ranged from 0.13 to 0.46 mg/kg with the highest values in common mergansers. Most pesticides and herbicides were either not detected or very low. Concentrations of aroclor (PCBs) were detected in all waterfowl sampled with values ranging from 0.002 to 4.873 mg/kg. Because there are no criterion for assessment the significance of these results is not known.

1.8.4 Fish Tumours or Other Deformities

A relatively high incidence of liver tumours in bullheads from Munuscong Bay, which was observed in a regional investigation carried out by the U.S. Fish and Wildlife Service (Paul Baumann, U.S.FWS, pers. comm). An explanation for the cause of the liver tumours could not be determined.

A fish tumour survey was conducted by OMOE in the St. Marys River during 1987. White suckers captured below the Rapids along the Ontario shoreline showed significantly higher mixed function oxidases (MFO) in their livers (oxygenating enzymes induced by exposure to certain chemicals) than fish captured from Batchawana Bay (control site) in Lake Superior. This increase likely reflects localized contamination in the sediments, water and benthic invertebrates of the St. Marys River (Smith *et al.*, 1991). An abnormal incidence of liver neoplasms has also been identified in white suckers from the St. Marys River; however, the frequency was also elevated in suckers from the control population in Batchawana Bay. This data is being re-evaluated (Smith, OMOE, unpublished data).

1.8.5 Bird or Animal Deformities or Reproductive Problems

There have been neither deformities documented nor reproductive problems reported in the St. Marys River AoC. However, predators of young gulls may potentially be adversely effected due to the increasing numbers of herring gulls, combined with low concentrations of PCBs, DDE, and other organochlorines in their eggs.

1.8.6 Degradation of Benthos

Benthic macroinvertebrate communities are impaired along the Ontario shore downstream of the Algoma Steel, St. Marys Paper and Sault Ste. Marie East End WPCP as evidenced by the presence of pollution-tolerant species and low diversity. Complete recovery of the benthic communities occurs in the lower section of Lake George, 24 km (15 miles) downstream from the industrial discharges. Sediments within the Algoma Slip are acutely lethal to the larvae of the burrowing mayfly *Hexagenia limbata*. Sediments which have visible oil are characterized by the absence of *Hexagenia limbata* nymphs.

Clean water fauna characterize the entire Michigan shore with the exception of the north side of Sugar Island and localized portions of Lake Nicolet.

1.8.7 Restrictions on Dredging Activities

Dredge spoils from the navigation channel have always been approved for open water disposal (USACOE Data Files). Sediments dredged from the Algoma Slip are disposed of on upland facilities. Contaminants in sediments from the Algoma Slip exceed the most stringent Ontario OWDG or "moderately polluted" U.S. EPA guidelines for dredged materials. These contaminants include iron, zinc, cyanide and oil and grease. In addition, total PAHs exceeded the proposed Ontario Sediment Quality Guideline of 2.0 mg/kg.

Sediments downstream of the Algoma Slip and along the Ontario shore, in Little Lake George and Lake George exceeded guidelines for dredged materials (OWDG and U.S. EPA) for iron, chromium, zinc, lead, arsenic, manganese, nickel, copper, oil and grease, PCBs, LOI, total phosphorus and TKN. Total PAHs exceeded the proposed Ontario Sediment Quality Guideline at these locations.

Lake Nicolet exceedences included iron, chromium, zinc, lead, arsenic, manganese, nickel, copper, cadmium, oil and grease, PCBs, LOI, total phosphorus, and TKN. Chromium, nickel, copper, mercury (one sample), and PCBs were exceeded in Munuscong Lake. Chromium and cadmium exceedences occur at the head of the St. Marys River along the Michigan shore at the Cannelton Industries waste disposal site.

1.8.8 Eutrophication or Undesirable Algae

The open waters of the St. Marys River are characterized by phytoplankton which are typical of oligotrophic waters (i.e., no evidence of eutrophication). Citizens' reports have identified localized impairments due to the presence of algae floating on the river in some embayments and other slow-moving portions of the river. In 1990, large algal mats were reported floating downstream of the East End WPCP.

1.8.9 Restrictions on Drinking Water Consumption or Taste and Odour Problems

1.8.9.1 Consumption, Taste and Odour

In Michigan, ambient water quality conditions do not restrict use of the St. Marys River, subsequent to standard treatment, as a source of potable water. The City of Sault Ste. Marie, Ontario now obtains approximately 50% of its drinking water from an intake located in near-shore Lake Superior at Gros Cap, upstream of point source discharges. Drinking water is also obtained from city wells. There have been no instances in Sault Ste. Marie, Ontario where restrictions have been implemented by the Algoma Health Unit for the consumption of treated drinking water (Wes Terry, Algoma Health Unit, pers. comm.) however, federal, state and local agencies advise against the consumption of surface water prior to standard treatment.

1.8.9.2 Tastes and Odour Problems

Densities of blue-green or chrysophytic algae and concentrations of phenolic compounds do not occur at levels which would adversely affect taste and odour of treated drinking water. Taste and odour problems have not been reported for St. Marys River water.

1.8.10 Impairment of Ambient Water Quality

Ambient water quality criteria have been exceeded in the St. Marys River. Exceedences of dissolved oxygen, turbidity, phenols, total and unionized ammonia, cyanide, iron, total phosphorus, PAHs and bacteria have been documented downstream of Ontario industrial and municipal discharges along the Ontario shoreline.

1986/87 sampling indicates that cyanide levels were below the PWQO and MWQS criteria. Levels of bacteria and phenols showed exceedences in Michigan waters downstream of the locks. Bacterial densities, total phosphorus and free and unionized ammonia exceeded PWQO and MWQS downstream of the East End WPCP in the Lake George Channel.

1.8.11 Beach Closings and Body Contact

Periodic advisories against swimming and bathing have been issued in Michigan due to high bacterial densities downstream of combined sewer overflows however, there have been no beach closings. The Sherman Park Beach, located upstream of all discharges, and the Sugar Island Township Park beach, located on Sugar Island, have not been closed and high levels of bacteria have not been found.

Fecal coliform bacterial densities in excess of the PWQO and MWQS occur in Ontario waters downstream of storm sewers, industrial outfalls and the East End WPCP.

1.8.12 Degradation of Aesthetics

Floating scum along the north shore of Sugar Island in Michigan is periodically reported. In Ontario, mats of oily fibrous material mixed with wood chips occasionally occur between Sault Ste. Marie and the Lake George Channel. As well, oil slicks appear from time to time downstream from the Algoma Slip and Terminal Basin. Since March 1990, no complaints of floating oil have been received. This may be a result of improvements made at Algoma Steel (G. LaHaye, OMOE, pers. comm.).

1.8.13 Added Cost to Agriculture or Industry

In both Michigan and Ontario, no additional costs have been required to treat water prior to use in either agriculture or industry.

1.8.14 Degradation of Phytoplankton and Zooplankton Populations

In open water phytoplankton and zooplankton populations are low in terms of abundance and relatively diverse in terms of community structure and reflect the oligotrophic characteristics of Lake Superior waters.

Phytoplankton and zooplankton populations have not been documented in nearshore areas of the St. Marys River where waters are slow moving and residence is long. There is no information to determine if plankton populations are impaired by contaminants. An assessment of plankton in embayments and slow-moving waters is required because of impaired ambient water quality.

1.8.15 Loss of Fish and Wildlife Habitat

Fish spawning and rearing habitat in both Michigan and Ontario have been lost due to the construction of structures for navigation and power generation, as well as from dredging and filling activities.

Pollutant loadings from industrial and municipal discharges and urban runoff affects sediment quality and benthic habitat along the Ontario shore.

Large ships utilizing the Seaway channel impact on sediments and littoral habitat. Temporary drawdowns due to ship passage may also negatively impact benthos and larval fish in emergent wetlands.

On-going aggregate extraction in Whitefish Bay of Lake Superior is being monitored to determine impacts on whitefish spawning grounds.

1.9 SOURCES AND LOADS

Contaminant loadings data are summarized for point sources including Algoma Steel, St. Marys Paper, two Ontario WPCPs, one Michigan WWTP and three Ontario tributaries as well as for non-point sources. The evaluation of non-point source loadings is based on limited data. For example, loadings data from non-point sources such as atmospheric deposition, urban runoff from the Sault, Michigan and from contaminated sediments are not available for comparison. Data limitations for point sources relate primarily to the lack of recent loadings at all facilities for parameters not monitored for compliance purposes (especially trace metals and organic contaminants).

Point sources contributed the greatest loadings of most contaminants as compared to non-point sources. In particular, point sources contributed the greatest loadings of oil and grease, phosphorus, ammonia-N, suspended solids, chloride, iron, lead, mercury, zinc, cyanide, phenols and PAHs. Non-point sources contributed the largest loads of nickel (65%), PCBs (100%) and copper (29%) as well as relatively large loadings of zinc (25%), lead (37%), mercury (16%), chloride (17-29%) and PAHs (34-44%). The primary non-point source identified was urban runoff from Sault Ste. Marie, Ontario.

The primary and secondary sources of contaminants and the percentage of the total loadings contributed by each source are identified in Table 1.2, based on data collected between 1986 and 1988 and 1989/1990 data from the Michigan WWTP. Loadings calculated from the data which are currently available indicate that Algoma Steel is the primary loading source of oil and grease, ammonia-N, suspended solids, chloride, iron, lead, mercury, zinc, cyanide, phenols and PAHs (Table 1.2). The East End WPCP is the primary contributor of phosphorus, and non-point loadings are the primary sources of copper, nickel and PCBs.

Oil and grease in the St. Marys River AoC have been identified as the major cause of use impairments related to the degradation of benthic fauna and to the degradation of aesthetics (visual impairments). Together, the East End WPCP and Algoma Steel are identified as contributing over 88 percent of this contaminant to the river. St. Marys Paper is the third largest contributor of oil and grease.

Fish consumption advisories are in place due to contamination by mercury. Algoma Steel contributes the largest of the known loadings of mercury to the river. However, mercury from atmospheric deposition and the erosion of soils and bedrock, are believed to be the primary cause of this since similar consumption advisories exist for Lake Superior as well.

Use impairments related to sediment contamination have been identified, based on exceedences of OMOE and U.S. EPA guidelines for the disposal of dredged material. The primary sources of parameters which exceed guidelines are Algoma Steel for oil and grease, cyanide, lead, mercury, zinc, iron, and PAHs; urban runoff and tributaries for nickel; and atmospheric for PCBs. Copper is contributed primarily from non-point sources (urban runoff), tributaries and the East End WPCP. Sources of chromium and arsenic resulting in exceedences of guidelines are not well documented, however, the Cannelton Industries Site serves as a non-point source (erosion) of chromium. Exceedences of sediment arsenic concentrations occurred in the Algoma Slip.

Although not directly associated with use impairments, PAH concentrations in mussel tissue has been identified. The primary source of the PAHs are Algoma Steel outfalls with secondary sources associated mainly with urban runoff. The source of the PAHs to urban runoff is not well understood but atmospheric pathways are involved.

Ambient water quality criteria have been exceeded in Ontario waters by concentrations of dissolved oxygen, turbidity, total phenols, total and unionized ammonia, free cyanide, iron, total PAHs, total phosphorus and bacteria. Algoma Steel is the major contributor of phenols, iron, and in past years total ammonia and cyanide; the East End WPCP is the major source for total phosphorus, total and unionized ammonia and bacteria. Other sources of fecal coliform bacteria are, CSOs (Michigan), and stormwater runoff. Ambient water quality criteria for phenols were exceeded in Michigan waters near Sugar Island.

Table 1.2 Primary and secondary sources of contaminants to the St. Marys River AoC based on loadings data collected from 1986 through 1988 (percent of total loading shown in brackets).

Contaminant	Primary Contributor	Secondary Contributor
Oil and Grease	Algoma Steel (76.3%)	East End WPCP (10.8%)
Total Phosphorus	East End WPCP (45.0%)	Algoma Steel (16.7%)
Ammonia-N	Algoma Steel (92.5%)	East End WPCP (4.8%)
Suspended Solids	Algoma Steel (36.2%)	St. Marys Paper (21.2%)
Chloride*	Algoma Steel (54.1%)	Non-Point (29.0%)
Copper	Non-Point (29.3%)	East End (26.2%)
Iron	Algoma Steel (81.6%)	Non-Point (8.9%)
Lead	Algoma Steel (41.4%)	Non-Point (37.0%)
Mercury	Algoma Steel (74.6%)	Non-Point (16.4%)
Zinc	Algoma Steel (60.7%)	Non-Point (24.6%)
Nickel*†	Non-Point (64.5%)	Root River (22.3%)
Cyanide	Algoma Steel (99.7%)	Non-point (0.1%)
Total Phenols	Algoma Steel (98.5%)	St. Marys Paper (0.4%)
Total PCBs	Non-Point (100%)	
Total PAHs*	Algoma Steel (45.9%)	Non-Point (34.2%)

* Percentage calculated using maximum values of reported range.
† No point source data available.
Note: Loadings are compared on a relative (%) basis. Absolute loadings for some parameters are not significant based on comparison with guidelines/criteria.

2 INTRODUCTION

2.1 BACKGROUND

The Great Lakes are a unique natural resource containing 20% of the world's fresh surface water. These lakes also form a portion of the international boundary between the United States and Canada, and both countries have jurisdiction over their use.

The St. Marys River connects the two uppermost Great Lakes, Lake Superior and Lake Huron, and is a boundary between Michigan's upper peninsula and Ontario. The river supports large populations and diverse communities of fish, other aquatic life and wildlife. In addition, the river supports a variety of uses by humans, including but not limited to drinking and industrial water supply, and navigation. The St. Marys River is discussed in greater detail in Chapters 5 and 6 of this document.

To protect the Great Lakes and connecting channels, and cooperatively address problems along their common border, the U.S. and Canada interact through an agency known as the International Joint Commission (IJC). The IJC was established by the U.S. and Canada under the authority of the Boundary Waters Treaty of 1909 which sets forth the rights and obligations of both countries regarding all common boundary waters. The responsibilities of the IJC, as identified in the Boundary Waters Treaty include collecting, analyzing and disseminating data, and tendering recommendations to the U.S. and Canadian governments regarding water quality problems in the boundary waters. As far back as 1912, the U.S. and Canadian governments asked the IJC to investigate the extent and causes of pollution in the Great Lakes. The IJC identified specific locations, including the St. Marys River, that were polluted with raw sewage, and pollution sources, and recommended specific actions to control the pollution. Water borne disease epidemics were eventually eliminated from the Great Lakes basin as a result of such efforts.

Concern about other water quality problems, specifically cultural eutrophication, over the years resulted in the signing of the 1972 Great Lakes Water Quality Agreement (GLWQA) by the U.S. and Canadian governments. This agreement affirmed both countries' determination to restore and enhance Great Lakes water quality, and established general and specific water quality objectives for the Great Lakes system.

Since 1973, the IJC's Great Lakes Water Quality Board (GLWQB) has identified specific areas throughout the Great Lakes basin having serious water quality problems. These problem areas have been described and evaluated in annual and biennial GLWQB reports. In 1973, these areas were called "Problem Areas", and they varied in size, complexity, and severity. Over the years, many of the problems have been resolved through the implementation of water quality standards, effluent regulations, industrial pretreatment programs, and construction and upgrading of wastewater treatment plants. As a result of these programs, and the identification of new concerns, there have been many subtractions from the original list of Problem Areas.

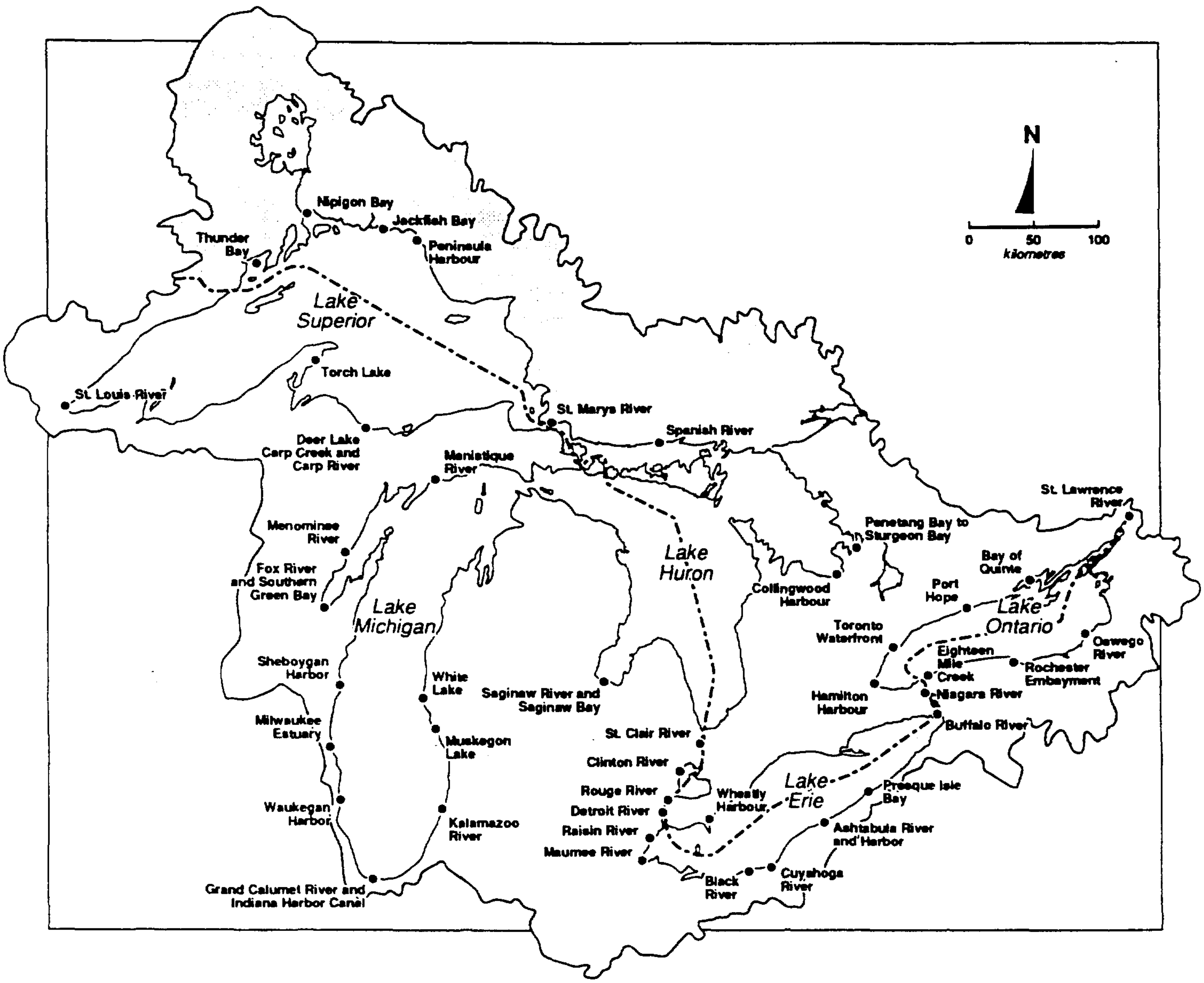
The GLWQB recognized that the Problem Areas' approach lacked consistency in problem identification and assessment, as it relied on water quality indications alone. In 1981, the Problem Areas were renamed "Areas of Concern" (AoCs). The name change reflected the IJC's desire to shift the problem perspective from water quality alone to an "ecosystem perspective" that is, based on environmental quality data for all media (i.e., water, sediment, and biota), and to evaluate the areas with uniform criteria. This new approach was consistent with the GLWQA of 1978. An AoC was defined by the GLWQB as an area where there is known impairment of a beneficial water use. In 1981, there were 39 AoCs that were divided into 2 classes based on the severity of the identified problems.

The GLWQB's Report on Great Lakes Water Quality identified 43 AoCs (Figure 2.1). The St. Marys River was identified as an AoC due to the following types of problems: conventional pollutants (i.e., phosphorus, bacteria), heavy metals, trace organics, contaminated sediments, fish consumption advisories and impacted biota. Sources were cited as municipal and industrial point sources, urban nonpoint sources, combined sewer overflows and contaminated sediments. It was noted in the 1985 report that no problems existed along the

Figure 2.1

St. Marys River Remedial Action Plan

Location of the 43 Areas of Concern in the Great Lakes Basin as identified by the Great Lakes Water Quality Agreement 1985



Michigan shoreline. Since that time, cross-boundary movement of pollutants has been documented, and impacts noted.

In its 1985 report, the GLWQB also presented a new approach for categorizing the AoCs based on the status of the data base, programs underway to fill data gaps, and remedial actions taken to address the identified problems. No effort was made to classify the AoCs on the severity of the problems. The jurisdictions and the IJC acknowledged that additional, specific guidance was needed to resolve the persistent pollution problems that remained in most of these AoCs. Accordingly, the eight Great Lakes states and the Province of Ontario agreed to develop Remedial Action Plans (RAPs), or clean up plans, for those AoCs within their jurisdictional boundaries. Because the St. Marys River is an international waterway, this RAP is being developed as a binational effort with Ontario and Michigan serving as lead agencies.

2.2 REMEDIAL ACTION PLANS AND THE AREAS OF CONCERN PROGRAM

In 1987, the U.S. and Canadian governments signed a Protocol to amend the *Revised Great Lakes Water Quality Agreement of 1978*. The Protocol adds specific programs, activities and timetables that more fully address issues identified in the 1978 GLWQA. Annex 2 of the 1987 Protocol requires the development and implementation of RAPs to restore beneficial uses in the Great Lakes AoCs. These RAPs are to serve as an important step toward the virtual elimination of persistent toxic substances, and toward restoring and maintaining the chemical, physical and biological integrity of the Great Lakes basin ecosystem. The Protocol now established that the state, provincial, and federal governments were responsible, for the development, (approval) and implementation of RAPs. The IJC will, in its advisory role, review RAPs as they are developed, and track their implementation.

An AoC is defined in Annex 2 as, "...a geographic area that fails to meet the General or Specific Objectives of the Agreement where such failure has caused or is likely to cause impairment of beneficial use or of the area's ability to support aquatic life". Fourteen impaired uses are specified, and the existence of any one could be sufficient to list an area as an AoC. The fourteen impaired uses are:

(i) Restrictions on fish and wildlife consumption;
(ii) Tainting of fish and wildlife flavour;
(iii) Degradation of fish and wildlife populations;
(iv) Fish tumours or other deformities;
(v) Bird or animal deformities or reproduction problems;
(vi) Degradation of benthos;
(vii) Restrictions on dredging activities;
(viii) Eutrophication or undesirable algae;
(ix) Restrictions on drinking water consumption, or taste and odour problems;
(x) Beach closings;
(xi) Degradation of aesthetics;
(xii) Added costs to agriculture or industry;
(xiii) Degradation of phytoplankton and zooplankton populations; and
(xiv) Loss of fish and wildlife habitat.

In 1988, the GLWQB developed additional guidance to the parties and jurisdictions to identify AoCs and the impaired uses. Proposed Listing and Delisting Criteria for Great Lakes AoCs (Appendix 2.1) identified specific types of geographic areas that were eligible, and established listing and delisting criteria for each of the 14 use impairments. As some of the criteria tend to be subjective, the jurisdictions, parties and IJC must exercise good, sound judgment when listing AoCs, and when defining which uses are impaired. The goal of the AoC program, which is to address specific problems that affect the Great Lakes, must be kept in mind at all times.

Annex 2 of the Protocol amending the GLWQA specifies that the RAP should be submitted to the IJC for review and comment at three stages. The three stages and the contents of the RAP at each stage are as follows:

> Stage 1: The problem(s) in the AoC must be defined, including: (i) definition and detailed description of the environmental problem(s) in the AoC, and confirmation of beneficial uses that are impaired, the degree of impairment and the geographical extent of the impairment; and (ii) identification of causes of the use impairments, including a description of all known sources of pollutants and an evaluation of other possible sources.
>
> Stage 2: The specific goals for the AoC must be defined, and the remedial and regulatory measures selected to meet those goals described. This document will include: (i) an identification and evaluation of remedial measures in place; (ii) an evaluation of alternative additional measures to restore beneficial uses; (iii) a selection of additional remedial measures to restore beneficial uses, and a schedule for their implementation; and (iv) an identification of persons, agencies, or organizations responsible for implementing the selected remedial measures.
>
> Stage 3: This portion of the RAP will be submitted when identified beneficial uses are restored. The Stage 3 RAP will include: (i) a process for evaluating the implementation and effectiveness of remedial measures; and (ii) a description of surveillance and monitoring processes to track the effectiveness of remedial measures, and the eventual confirmation of the restored impaired uses.

2.3 ST. MARYS RIVER REMEDIAL ACTION PLAN

Today, the St. Marys River is used extensively for: commercial and recreational boating; fishing; swimming; hydro power generation; drinking and process water; and municipal and industrial waste assimilation for the twin cities of Sault Ste. Marie, Michigan and Sault Ste. Marie, Ontario. The cities have a combined population of about 100,000, with 85,000 residing in Sault Ste. Marie, Ontario.

However, development has not been without its environmental consequences. While water entering the river from Lake Superior continues to be of excellent quality, industrial and municipal discharges in the Sault Ste. Marie, Ontario area, and to a lesser extent, downstream from Sault Ste. Marie, Michigan, have resulted in contaminated water, sediment and biota. As well, fish and wildlife habitat has been substantially altered and/or eliminated through construction of navigation locks, canal and dam structures, compensating works, hydro facilities, and shoreline filling and dredging.

This document is intended to meet the requirements of a Stage 1 RAP for the St. Marys River. The problems, their causes, and the sources of pollutants of concern, as known to date, have been defined by the public, Michigan Department of Natural Resources (MDNR), Ontario Ministry of the Environment (OMOE) and other participating federal, provincial, state and local agencies. This RAP contains the technical documentation that will be used by the agencies and public when determining the water uses and goals for developing the Stage 2 RAP. In turn, the goals will establish the general direction for future remedial actions.

In developing this Stage 1 RAP, available environmental quality data were compared with the "listing criteria" to determine which uses are impaired. Ambient water and effluent quality data were compared with various water quality standards and effluent requirements to detect violation of existing standards and guidelines. Once the impaired uses and (any) other problems were identified, the causes of these problems, and the sources and loadings of specific contaminants of concern were determined. The public (i.e., both individuals and organizations) and various levels and types of government agencies were included throughout the Stage 1 RAP development process (i.e., see Chapter 3) in an attempt to reach consensus on the problems in the

AoC. Involvement of those people and agencies directly responsible for developing this RAP will continue through the Stage 3 RAP. This is viewed as an important and necessary part of the RAP process if future improvements in the aquatic ecosystem are to reflect the scientific and economic realities, and public desires.

As suggested above, the RAP for the St. Marys River (i.e., all stages) will essentially be a framework for action. Coordinated and ongoing direction for responding to environmental problems, from problem recognition to achieving a desired level of rehabilitation, will be provided; in this regard, it will specifically include:

- a description of the river and its related uses;
- an outline of existing environmental conditions and problems;
- a description of beneficial uses that are impaired;
- an identification of the sources or causes of the use impairment(s);
- a goal statement and related objectives;
- the identification and evaluation of remedial actions to restore beneficial uses;
- a strategy for implementing the RAP, including confirmation of schedules, costs, jurisdictional responsibilities, prognosis, priority evaluation, and stakeholder involvement; and
- a process for evaluating remedial measure implementation and effectiveness, based on surveillance and monitoring until the restoration of beneficial uses is complete.

This RAP (i.e., all stages) is a technical planning document for addressing aquatic ecosystem problems in the St. Marys River. It is not the first of such efforts. Water pollution reduction programs have been ongoing for over 40 years. Nor is it the only effort. Regulatory agencies will continue their efforts to control pollutant sources and improve environmental quality as the RAP is developed. Remedial actions and regulatory measures that are identified and immediately implementable will proceed regardless of the status of RAP.

Development and implementation of this RAP is viewed as a long-term, iterative process. Periodic updates and revisions may be required as more data become available, remedial measures are implemented, and environmental conditions improve. The RAP process itself will eventually end when data confirm that identified beneficial uses have been restored, or that further use restoration is not possible. Although the RAP process may end, efforts to restore and enhance environmental quality will continue.

Material for this Stage 1 report has been extracted from numerous background technical reports, government publications, scientific papers and file correspondence. Of particular importance is *Upper Great Lakes Connecting Channels Study* (1986) and its various appendices, the *St. Marys River: An Ecological Profile* (Duffy *et al.*, 1987), the *1987 Report on Great Lakes Water Quality* prepared by the GLWQB, and *Limnological and Fisheries Studies of the St. Marys River, Michigan, in Relation to Proposed Extension of the Navigation Season, 1982 and 1983* (Liston *et al.*, 1986).

Also important are the results of unpublished data collected to confirm both old and emerging problems including: estimates of point and diffuse sources pollutants, zones and/or locations and sources of bacterial pollution, and heavy metals, and toxic organic contamination. As well, information on fish and wildlife habitat lost over the years.

3 PARTICIPANTS

3.1 THE REMEDIAL ACTION PLAN TEAM

The RAP for the St. Marys River AoC was initiated in 1985. Since the St. Marys River is a shared international boundary, Michigan, the U.S. Environmental Protection Agency (USEPA), Ontario, and Environment Canada are jointly responsible for its preparation. In 1985, an agreement was signed by Governor James Blanchard of Michigan and Premier David Peterson of Ontario establishing that a joint RAP would be prepared, and giving Ontario the lead role for this endeavour. In 1987, a RAP Team was established to develop the plan and ensure adequate and appropriate public involvement.

The RAP Team includes representatives from the federal, state, and provincial governments. The RAP Team is co-chaired by representatives from the MDNR and the OMOE. A complete list of RAP Team members is included in Appendix 3.1. By April 1989, four members of the Binational Public Advisory Council (BPAC) which is described in Section 3.2.3 were elected as delegates to the RAP Team to facilitate communication between the RAP Team and BPAC. The governmental members of the RAP Team are responsible for the actual writing of the RAP. Rap Team meetings are held as needed, generally bimonthly.

3.2 PUBLIC PARTICIPATION

3.2.1 Background

Development of the RAP has two major components: technical information compilation; and public participation. Public participation is an important and necessary component as it informs the public, improves the plan by gaining information and advice from the public, secures support for plan implementation, and provides a mechanism for accountability to the public. The importance of public consultation is underscored in Annex 2 of the amended GLWQA, which requires that the parties, in cooperation with state and provincial governments consult with the public as part of RAP development.

The need for a comprehensive public participation program for the St. Marys River was recognized early in the process. The OMOE, as lead agency for the St. Marys River RAP, retained a consultant to assist in developing a public participation program.

To assist in the dissemination of information, the RAP Team established six reference centres (Appendix 3.2), and developed a St. Marys River RAP Newsletter (see Appendix 3.2 for an example). The newsletter is available to all interested citizens. It is used to highlight various issues of concern regarding St. Marys River water quality, and to keep citizens apprised of the activities of the BPAC and the RAP Team.

3.2.2 Displays

Display panels were designed to communicate the goals and objectives of the St. Marys River RAP to the public. The display has been used at various community events, and has been successful at broadening public awareness about the clean-up plan.

3.2.3 Public Meetings

Two initial public information sessions were held on February 10, 1988, one in Sault Ste. Marie, Michigan and one in Sault Ste. Marie, Ontario. Formal discussions at these sessions consisted primarily of presentations by the RAP Team on the RAP process, documented water quality problems in the river, and the public involvement program. However, the primary purpose of these sessions was to develop a rapport with citizens, and to encourage one-on-one, informal discussions. One hundred and five people attended the afternoon information session held in Ontario, with seventy-two attending the evening session in Michigan.

A second public meeting was held in Sault Ste. Marie, Ontario on June 16, 1988; this was attended by 61 persons. The topics of discussions were point sources, fish consumption advisories, and formation of BPAC. A great deal of time was allocated for attendees to make formal statements regarding their concerns.

A third public meeting was held April 3, 1989. This was a joint public/BPAC meeting for purposes of presenting the findings and conclusions of the Upper Great Lakes Connecting Channels Study (UGLCCS). A complete listing of the public meetings, including locations, is found in Appendix 3.3.

3.2.4 Binational Public Advisory Council

The public participation plan which was agreed to by the St. Marys River RAP Team included the formation of the BPAC to provide a channel for informed and continuous public participation. The St. Marys River BPAC was created during the summer and fall of 1988. The BPAC advises the RAP Team on all aspects of the planning process including: water use goals, problem identification, planning methodology, technical data, remedial action alternatives, plan recommendations, and plan adoption.

The council consists of fourteen Ontario members and ten Michigan members from the following community sectors:

- Environment;
- Recreation/Tourism;
- Industry/Shipping/Small business;
- Labour;
- Fisheries;
- Municipalities;
- Academic;
- Elected Officials;
- Citizens at large;
- Public Health; and
- Native Peoples

Many of the persons nominated for the BPAC were identified as a result of their interest and informed participation at previous public meetings. A description of how the BPAC was established is provided by Schmidtmeyer (1989). A complete list of BPAC representatives is included in Appendix 3.4. Technical experts as well as a number of groups with a wide range of concerns and interests are represented on the BPAC.

The BPAC's adopted charge is as follows:

> The BPAC shall comment on and advise the RAP Team on key aspects of RAP preparation and implementation. This includes: the goals of the plan, problems to be addressed, water uses to be restored, planning methodology, technical data, remedial action alternatives, plan recommendations, and plan implementation. The goal of the BPAC is to arrive at a plan which both BPAC and the RAP Team can come to a consensus on, and for which there is broad public support and commitment.
>
> BPAC members shall relay relevant RAP information and decisions to members of the groups they represent and, where appropriate, shall seek ratification of BPAC resolution by groups within their constituencies.

The process of developing the RAP for the St. Mary River includes input and review and comment by the BPAC on the draft RAP as written by the RAP Team. To assist in this process, the RAP Team provides information and arranges for presentations to the BPAC as work progresses on the RAP. BPAC meetings are held as necessary, generally every 4-6 weeks. A complete list of BPAC meeting dates and discussion topics is presented in Appendix 3.3. As previously mentioned, four members of the BPAC were elected as delegates to the RAP Team. BPAC representation on the RAP Team has resulted in substantial contributions to ongoing discussions and to the writing process. The entire BPAC has reviewed and commented on the draft RAP chapters as they were completed by the RAP Team.

3.3 TECHNICAL EXPERTISE

Although a formal technical advisory committee was not organized to assist in developing the RAP, numerous experts were contacted to contribute relevant data, and to review the draft RAP for technical content and completeness. Individuals having expertise in various subjects relevant to the RAP were called on from state/provincial, local and federal governments, including the U.S. EPA, OMOE, Environment Canada, U.S. Geological Service, U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, Michigan Department of Public Health (MDPH), local health departments, and MDNR (i.e., Fisheries, Parks, Waste Management, Groundwater, Wildlife, Coastal Zone Management, Surface Water Quality, Environmental Response, etc.), local parks IJC, various universities, and others who had data and expertise to share. These individuals were also contacted for assistance with specific issues as questions arose, and to give presentations at BPAC and public meetings.

3.4 GOVERNMENT AGENCIES

Government agencies participating in the development of the St. Marys River RAP include the U.S. EPA, Canada Department of the Environment (DOE), MDNR, OMOE, Ontario Ministry of Natural Resources (OMNR) and Canada Department of Fisheries and Oceans (DFO). As specified in the 1985 letter of intent signed by Governor Blanchard and Premier Peterson, the OMOE has lead responsibility for developing this RAP. Members of the RAP Team from federal and state/provincial governments are responsible for the actual writing of all stages of the RAP. Upper level management from these agencies are responsible for reviewing and approving all stages of the RAP to be implemented by their respective agencies. Final versions of the RAP are submitted, by stage, to the IJC for review and comment. The IJC is responsible for tracking implementation of the RAPs. The agencies will incorporate appropriate IJC comments into future revisions of the RAP.

4 REGULATORY PROGRAMS

Numerous programs, regulations, objectives, guidelines and agreements to maintain and enhance environmental quality are in place and/or under development in Ontario, Michigan, and at the federal levels in both Canada and the United States. Many of the programs and regulations relevant to the control and enhancement of environmental quality in the St. Marys River AoC are outlined in this chapter. Legislation applicable to this discussion is listed in Appendix 4.1. The discussion is intended to outline the major aspects of the most important regulatory programs that affect environmental quality in the AoC. The chapter is organized by jurisdiction to point out the regulatory tools that each has to work with at this point in time. It is not the intent to compare or contrast programs, but rather to present information that will form the basis of many decisions affecting the AoC.

The determination of whether a beneficial use is impaired will be based on the IJC listing/delisting criteria (discussed in Chapter 2) and also to a large degree on compliance with existing policies, regulations, standards, etc. Of particular importance in this regard are the ambient water quality criteria that are established for the protection of water quality and/or water uses (by humans and other life). Although these criteria and their applications are discussed in detail under the appropriate jurisdictional section, Table 4.1 is provided as a quick reference. This table summarizes the Michigan Water Quality Standards, Ontario Provincial Water Quality Objectives and the Great Lakes Water Quality Agreement Specific Objectives for toxic substances. All will be used to assist in the determination of whether a use is impaired and whether exceedences of water quality standards occur. U.S. EPA criteria are not included because they are not directly applicable to the AoC.

The Stage 2 RAP will contain recommendations that are consistent with the legislation, policies, standards and programs described in this Chapter. Stage 2 may also recommend new programs or changes to existing regulatory programs if existing programs have been shown to be ineffective in protecting beneficial uses.

4.1 ONTARIO

4.1.1 Environmental Legislation

Environmental quality of the Great Lakes in Ontario is regulated by the province through federal and provincial environmental statutes (Table 4.2). Regulations promulgated under these statutes, (e.g. *Ontario Water Resources Act*, the *Ontario Environmental Protection Act* and the *Pesticides Act*) are intended to ensure that the quality of the water, biota, air, and lands are maintained within the province.

Many of these acts and regulations provide the legislative authority to control and restrict the discharge of contaminants into the air or water or onto the land. They specify numerous prohibitions that define what constitutes a contaminant and permitible discharge. The acts specify abatement mechanisms and procedures, such as Control Orders and Minister's Orders which are used to specify legally enforceable control strategies. The acts and regulations also specify permitting processes (Certificates of Approval) to ensure adequate collection, handling, treatment and disposal of wastes, including wastewaters, atmospheric discharges and solid wastes.

4.1.2 Water Quality Objectives

Ontario established goals and policies for the management of the quality and quantity of surface and groundwaters in 1978 under the *Ontario Water Resources Act*. Surface water quality must be satisfactory for aquatic life, recreation and potable water supply. The Provincial Water Quality Objectives (PWQOs) are a set of numerical and narrative criteria to protect aquatic life and recreation in and on surface water (OMOE, 1984).

Table 4.1 Applicable Surface Water Quality Criteria for Toxic Substances.

Chemical Name	Michigan Rule 57(2) Allowable Level (µg/L)[a]	Ontario Provincial Water Quality Objective (µg/L)	GLWQA Specific Objective (µg/L)
Arsenic	184.0	100	50.0
Cadmium	0.41(b)	0.2(e)	0.2
Chromium	48.10(b)	100	50.0
Copper	10.72(b)	5(f)	5.0
Cyanide	4.0	5	---
Lead	2.88(b)	1, 3, 5(g)	25.0
Nickel	33.34(b)	25	25.0
Selenium	20.0	100	10.0
Silver	0.1	0.1	---
Zinc	49.57(b)	30	30.0
Molybdenum	800.0	---	---
Paraquat	16.0	---	---
PCB	0.00002	0.001	---
Polybrominated Biphenyls	---	0(h)	---
Formaldehyde	171.0	---	---
DDT + metabolites	0.00023	0-0.003(h)	0.003
Phenol, 2,4-dinitro	9.8	---	---
Carbon tetrachloride	20.0	---	---
Chlordane	0.00053	0.06	0.06
Lindane	0.097	0.01	0.01
Phenol, 4-chloro-3methyl	4.4	---	---
Dieldrin	0.0000315	---	---
Aldrin/Dieldrin	---	0.001(h)	0.001
Aniline	4.0	---	---
Acetone	500.0	---	---
Chloroform	43.0	---	---
Hexachloroethane	13.0	---	---
Benzene	60.0	---	---
Ethane, 1,1,1-trichloro	117.0	---	---
Bromomethane	11.0	---	---
Vinyl chloride	3.1	---	---
Methylene chloride	59.0	---	---
Ethylene oxide	56.0	---	---

Table 4.1 Cont'd

Chemical Name	Michigan Rule 57(2) Allowable Level (µg/L)[a]	Ontario Provincial Water Quality Objective (µg/L)	GLWQA Specific Objective (µg/L)
Bromoform	65.0	---	---
Bromodichloromethane	24.0	---	---
Ethylene, 1,1-dichloro	2.6	---	---
Heptachlor	0.002	---	---
Heptachlor/Heptachlor Epoxide	---	0.001	0.001
Hexachlorocyclopentadiene	0.5	---	---
Isophorone	860.0	---	---
Propane, 1,2-dichloro	64.0	---	---
Ethane, 1,1,2-trichloro	65.0	---	---
Trichloroethylene	94.0	---	---
Acrylamide	900.0	---	---
Ethane, 1,1,2,2-tetrachloro	30.0	---	---
Pentachlorophenol < = pH 8.1	20.23(c)	0.5	---
Pentachlorophenol > = pH 8.1	23.0	0.5	---
2,4,6-Trichlorophenol	1.5	---	---
Dinoseb	0.80(c)	---	---
Naphthalene	29.0	---	---
Benzidine, 3,3-dichloro	0.06	---	---
Benzidine	0.0399	---	---
Silvex	21.3	---	---
Acetic Acid, 2,4-dichlorophenoxy	46.7	4.0	---
Benzene, 1,2-dichloro	7.0	2.5	---
Phenol, 2-chloro	10.0	---	---
Ethylbenzene	30.0	---	---
Styrene	19.0	---	---
Benzene, 1,4-dichloro	15.0	4.0	---
Phenol, 4-chloro	9.3	7.0	---
Ethylene dibromide	1.10	---	---
Acrolein	3.0	---	---
Ethane, 1,2-dichloro	560.0	---	---
Acrylonitrile	2.20	---	---
Toluene	100.0	---	---
Chlorobenzene	71.0	---	---

Table 4.1 Cont'd

Chemical Name	Michigan Rule 57(2) Allowable Level (µg/L)[a]	Ontario Provincial Water Quality Objective (µg/L)	GLWQA Specific Objective (µg/L)
Phenol	110.0	1	---
Bis(2-chloroethyl)ether	4.20	---	---
Bis(2-chloroethoxy) methane	4.60	---	---
Hexachlorobenzene	0.0018	0.0065	---
Benzene, 1,2,4-trichloro	22.0	0.5	---
Phenol, 2,4-dichloro	37.74(c)	0.2	---
1,4-dioxane	2000.0	---	---
Chlorodibromomethane	29.0	---	---
1,2,3,5-Tetrachlorobenzene	---	0.1	---
1,2,3-Trichlorobenzene	---	0.9	---
1,2,4,5-Tetrachlorobenzene	---	0.15	---
Pentachlorobenzene	---	0.03	---
Tetrachlorophenols	---	1.0	---
Trichlorophenols	---	16	---
Dibutylphthalate	---	4	---
Diethylhexylphthalate	---	0.6	---
Other phthalates	---	0.2	---
Tetrachloroethylene	16.0	---	---
Ethylene, t-1,2-dichloro	300.0	---	---
Benzene, 1,3-dichloro	179.0	2.5	---
1,2,3,4-Tetrachlorobenzene	0.76	0.1	---
Xylene	59.0	---	---
Tetra n-butyl ammonium bromide	140.0	---	---
2,3,7,8-TCDD	0.000000014	---	---
Di-n-propyl formamide	63.0	---	---
Mercury, methyl	0.0013	---	---
Mercury, total filtered	---	---	0.2
Mercury, filtered	---	0.2	---
Vanadium	3.73	---	---
Ammonia, unionized (coldwater)	20.0	20.0(d)	20.0
Ammonia, unionized (warmwater)	50.0	20.0(d)	---
Ammonia, total	---	---	500.0
Fluorides (soluble fluorides)	2000.0	---	---

Table 4.1 Cont'd

Chemical Name	Michigan Rule 57(2) Allowable Level (µg/L)[a]	Ontario Provincial Water Quality Objective (µg/L)	GLWQA Specific Objective (µg/L)
Fluoride, total	---	---	1200.0
Chlorine	6.0	2.0	---
Hydrogen sulfide	0.55	2.0	---
DBNPA	4.0	---	---
Chromium, hexavalent	2.0	---	---
Bis(chlorobutyl)ether	60.0	---	---
Total Resin Acids	---	1-61.5(i)	---
Methoxychlor	---	0.04	0.04
Mirex (mg/L)	---	0-0.001(h)	substant. absent
Toxaphene	---	0.008	0.008
Phthalatic esters	---	---	0.2 - 4.0
Endrin	---	0.002	0.002
Chlorpyritos	---	0.001	---
Diazinon	---	0.08	---
Dicamba	---	200	---
Diquat	---	0.5	---
Diuron	---	1.6	---
Dalapon	---	110	---
Endosulphan	---	0.003	---
Fenthion	---	0.006	---
Guthion	---	0.005	---
Malathion	---	0.1	---
Parathion	---	0.008	---
Pyrethrum	---	0.01	---
Simazine	---	10	---

Comment Codes

a) See Table 4.13 for basis. January 15, 1991 Update.
b) Based on a water hardness of 100 mg/L.
c) Based on a pH of 8.0.
d) pH and temperature dependent, not to exceed 20 µg/L unionized
e) In waters with hardness between 0-100 mg/L as $CaC0_3$. For waters with hardness 100 mg/L PWQO is 0.5 µg/L.
f) PWQO is 1 µg/L for hardness between 0-20 µg/L as $CaC0_3$; 5 µg/L for hardness 20 µg/L as $CaC0_3$.
g) Inorganic lead for hardness of 0-30, 30-80 and 80 mg/L, respectively.
h) As per narrative outlined in OMOE 1984 "Blue Book".
i) pH dependent (Note: PWQG Guideline).

Table 4.2 Environmental Legislation Affecting the Great Lakes and Connecting Channels.

Ontario Acts	Media or Activity Addressed												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Ontario Water Resources Act (OWRA)	1	3	1	1	1					2		1	
Ontario Environmental Protection Act (EPA)	3	2	3	1	1	1	1	2	1	3	1		2
Environmental Assessment Act	3	3	3	3	3	3		3	3	2	1		
Dangerous Goods Transportation Act			1			1				1			
Drainage Act													
Pesticides Act													
Public Lands Act													

Key to Codes

A: Ambient Surface Water and Ground Water Quality and Management
B: Sediment Quality and Management
C: Biota Quality and Habitat Management
D: Industrial Point Source Discharge Control
E: Municipal Point Source Discharge Control
F: Solid and Hazardous Waste Management
G: Pesticide Manufacture and Management
H: Urban Runoff and Combined Sewer Overflow Management
I: Air Point Source Discharge and Ambient Air Quality Control
J: Agricultural Land Management
K: Spills and Shipping Activities
L: Drinking Water Quality Control and Management
M: Fish Consumption Guidelines or Advisories

1: Legislation is responsible for legally enforceable standards and/or has direct authority over the media or activity.
2: Legislation provides non-enforceable guidance or authority over media or activity.
3: Legislation is not directly applicable to the media or activity, but media/activity may be impacted by execution of its legislative mandate.

Table 4.3 Ontario Provincial Water Quality Objectives (PWQO) for the protection of aquatic life and recreational uses.

Parameter	PWQO*
Alkalinity	25% decrease*
pH	6.5-8.5
Phosphorus(total),mg/L	10-30*
Sulphate, mg/L	
Taste Temperature, °C	10°C increase or max 30°C*
Total Dissolved Solids, mg/L	
Total Organic Carbon, mg/L Turbidity	10% secchi depth increase
Ammonia, mg/L	0.02*
Barium, mg/L	
Boron, mg/L	
Chloride, mg/L	
Chlorine, mg/L	0.002
Colour, TCU	
Copper, mg/L	
Cyanide (free), mg/L	0.005
Dissolved Gases	110% Sat.
Dissolved Oxygen, mg/L	4-8
Fluoride, mg/L	
Hydrogen Sulfide, mg/L	0.002
Manganese, mg/L	
Methane, $1/m^3$	
Nitrate (as N), mg/L	
Nitrite (as N), mg/L	
Heavy Metals, µg/L	
Arsenic	100
Beryllium	11-1100*
Cadmium	0.2
Chromium	100
Copper	5
Iron	300
Lead	5-25*
Mercury	0 to 0.2*
Nickel	25
Selenium	100
Silver	0.1
Zinc	30
Uranium, mg/L	

Table 4.3 cont'd

Parameter	PWQO*
Bacteria (per 100ml)*	
Standard Plate Count	
Total Coliform	1000
Fecal Coliform	100
Fecal Streptocci	
Pseudomonas aeruginosa	
Staphylococcus aureus	
Trihalomethanes, mg/L	
Industrial Organics, mg/L	
Dibutylphthalate	4
Diethylhexyphthalate	0.6
Other Phthalates	0.2
Mirex	0-0.001*
Polychorinated Biphenyls	0-0.001*
Polybrominated Biphenyls	0*
Oil & Grease†	
Phenols, μg/L	1
Radionuclides, Bq/L*	
Cesium 137	50
Iodine 131	10
Radium 226	1
Strontium 90	10
Tritium	40,000
Pesticides, μg/L	
Aldrin/Dieldrin	0.001*
Carbaryl	
Chlordane	0.06
Chlorpyrifos (Dusban)	0.001
Diazinon	0.08
Dicamba (Banvel)	200
Diquat	0.5
Diuron	1.6
Dalapon	110
Endosulphan	0.003
Endrin	0.002
Fenthion (Baytex)	0.006
Guthion	0.005
Heptachlor & Heptachlor Epoxide	0.001
Lindane	0.01
Malathion	0.1
Methoxychlor	0.04
Methyl Parathion Parathion	0.008

Table 4.3 cont'd

Parameter	PWQO*
Pyrethrum	0.01
Simazine	10
Toxaphene	0.008
DDT & Metabolites	0-0.003*
2,4-D (BEE)	4
2,4,5-TP	
Dibenzofurans/dioxins (pg/L)	

* From OMOE (1984) Water Management, Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment, Toronto.

† Oil and Grease guideline is a narrative which states: "Oil or petrochemicals should not be present in concentrations that:

- can be detected as a visible film, sheen, or discolouration on the surface;
- can be detected by odour;
- can cause tainting of edible aquatic organisms;
- can form deposits on shorelines and bottom sediments that are detectable by sight or odour, or are deleterious to resident aquatic organisms." (OMOE 1984).

Numerical PWQOs are given in Table 4.3. PWQOs represent a desirable level of water quality that the OMOE strives to maintain in surface waters of the province. They are often the starting point in deriving effluent requirements.

The PWQOs are under constant review and may be revised as more information becomes available. In 1984 the Ministry of the Environment had more than 70 substances with undefined tolerance limits for which there was insufficient scientific data to establish PWQOs (OMOE, 1984). The list continues to grow. In 1989 the Ministry issued the Handbook for the Parameter Listing System which summarized the various drinking water quality limits established by some 16 agencies worldwide for more than 600 compounds. The presence and/or discharge of these compounds is evaluated on a case-by-case basis.

The protection and control of water quantity focuses primarily on flood and erosion control. These are the responsibility of the Ontario Ministry of Natural Resources and local Conservation Authorities. OMOE has the responsibility of issuing 'water taking permits' under the *Ontario Water Resources Act*.

4.1.3 Point Source Controls

Municipal and industrial direct discharges to receiving waters are controlled by Ontario's Municipal and Industrial Effluent Objectives (Table 4.4) established under the OWRA and the EPA. In addition, site-specific effluent requirements protect the quality of the receiving water. Site specific requirements are based on Policy 3 of the Ministry's Water Management Goals, Policies, Objectives and Implementation Procedures (OMOE, 1984).

Policy 3 dictates that effluent limits will be established based on the waste receiving capacity of a waterbody and the Provincial Water Quality Objectives. Consideration will also be given to the Federal or Provincial effluent regulations or guidelines, and control of nonpoint sources of pollution. Effluent requirements will be determined following appropriate site specific receiving water assessments. This effluent requirement will be compared to Federal effluent regulations or Provincial effluent regulations or guidelines for existing or proposed new or expanded effluent discharges. The more stringent of the effluent requirement, regulations or guidelines will be imposed. The effluent requirement derived from this procedure for proposed new or expanded discharges will be incorporated into a Certificate of Approval in both waste loadings and concentrations.

Table 4.4 Ontario Municipal and Industrial Effluent Objectives (mg/L unless noted).

Parameter	Ontario Industrial Effluent Objectives	Ontario Municipal Effluent Objectives
BOD5	15	20
Suspended Solids	15	25
Oil and Grease	15	15
Ammonia-Nitrogen	10	-
Fecal Coliforms, MF/100ml	-	400
pH, SU Units	5.5 - 9.5	6-9
Total Phenols	0.02	0.02
Total Phosphorus	-	1
Total Residual Chlorine	-	0.5
Cadmium	0.001	-
Chromium*	1.0	-
Copper*	1.0	-
Lead	1.0	-
Mercury*	0.001	-
Nickel*	1.0	-
Tin*	1.0	-
Zinc*	1.0	-

*Total metals concentration not to exceed 1.0 mg/L

Certificates of Approval (CofA) for treatment works are issued under the OWRA. In the past, the CofA was an approval to install pollution control equipment with the design specifications shown in the CofA. Recently, some approvals include legally enforceable effluent limits which appear in the CofA.

Certificates of Approval are also issued to municipal Water Pollution Control Plants (WPCPs). These CofA's usually only describe control equipment modifications or specifications; however, some do contain effluent limits.

The provincial EPA Sewage System Regulations set standards for the construction and operation of sewage systems and the licensing of related businesses. Certificates of Approval are required for all residential, commercial and light industrial septic systems. Municipal storm sewer-use by-law control parameters and limits specify the concentration of various parameters, mainly conventional pollutants and metals. Municipal sanitary sewer-use by-law control parameters are similar in scope and degree of control, and apply to all industrial dischargers to the municipal facility. Additional pretreatment requirements, such as technology-based pretreatment, are not specified. However, these by-laws contain a clause enabling the municipality to require oil interceptors, flow monitors, manholes and treatment, as necessary, to meet the by-law limits (without dilution).

Legally enforceable Control Orders may be issued under Section 113 of the EPA to any existing plant. Control Orders define tasks and compliance dates by which specific tasks must be completed.

The Guidelines for Control of Industrial Phosphorus Discharges in Liquid Effluents, issued under EPA, are intended to provide guidelines for phosphorus discharges and water quality management consistent with municipal sewage systems. The objective of 1 mg/L phosphorus concentration in industrial effluents is based on the use of practicable control technology to control or eliminate phosphorus. Facilities discharging one million gallons per day or more of effluent are subject to the phosphorus limitation of 1 mg/L.

The provincial government, in consultation with Environment Canada, published a White Paper entitled "Municipal-Industrial Strategy for Abatement (MISA)" in June, 1986. The White Paper provides the framework for the control of toxic contaminants in industrial and municipal effluents; initially, through a regulatory component to enforce technology-based effluent limits. The minimum pollution control requirement will be based on the implementation of "Best Available Technology Economically Achievable (BATEA)". As treatment technologies are advanced, BATEA requirements will be adjusted, moving towards the goal of virtual elimination of persistent toxic contaminants. This is consistent with the policies stated in the Great Lakes Water Quality Agreement as amended in 1987. Development of these controls will be accomplished through the promulgation of Effluent Monitoring Regulations and Effluent Limits Regulations directed at municipal and industrial sectors in order to achieve water pollution control at its source.

Opportunity for public involvement has been afforded and is summarized in Public Review of the MISA White Paper and the OMOE's Response (MISA OMOE 1987). Under the MISA program, a monitoring regulation sets legal requirements for sampling, analysis (including quality assurance and quality control), toxicity sampling, flow monitoring and reporting of self-monitoring information. This new regulation specified a list of pollutants for monitoring as per the Effluent Monitoring Priority Pollutants List (EMPPL-OMOE 1987) and a set of sampling schedules for each defined industrial and municipal sector.

The EMPPL is a list of toxic pollutants that have been detected or are potentially present in Ontario municipal and industrial effluent and pose a hazard to the receiving environment. The 1988 EMPPL update (OMOE 1989) contains 266 chemicals and includes 179 parameters from the 1987 EMPPL and 87 additional parameters.

Plants which directly discharge wastewater to surface watercourses and which are subject to the MISA effluent monitoring regulations of Ontario, were required to prepare Initial Reports under the monitoring regulations. These Reports provide details on effluent monitoring equipment, wastewater flow and process information of each discharger, that monitored effluent streams during a one year information gathering period.

The content of Initial Reports is defined by two regulations made under the *Environmental Protection Act*. These are Ontario Regulation 695/88 Effluent Monitoring - General, called the General Regulation, and a regulation covering an industrial grouping or sector called the Sector Regulation. When completed, the regulations will expand the available data base on toxic substances and result in greater uniformity in reporting.

Effluent Monitoring Regulations for the nine industrial sectors were promulgated as per the schedule shown in Table 4.5. The Ministry of the Environment is now in the process of formulating effluent limit regulations for each industrial sector based on the best available technology economically achievable. It is anticipated that the Limits Regulations for the nine industrial sectors will be promulgated by 1992. The data collected under the Effluent Monitoring Regulations will be used in combination with Best Available Technology to establish these limits.

Sampling methodologies and frequencies, analytical protocols, definitions and a list of the priority pollutants are presented in the following reports:

A Policy and Program Statement of the Government of Ontario on Controlling Municipal and Industrial Discharges into Surface Waters (White Paper)	June, 1986
The Public Review of the MISA White Paper and the OMOE's Response to It	January, 1987

Table 4.5 MISA Monitoring Regulations Promulgation Dates.

Sector	Monitoring Regulation
Petroleum	July 1988
Organic	April 1989
Iron & Steel	May 1989
Mining	August 1989
Pulp & Paper	July 1989
Inorganic Chemicals	June 1989
Metal Casting	October 1989
Electric Power Generation	December 1989
Municipal STP	Being Revised
Industrial Minerals	December 1989

The Effluent Monitoring Regulation for the Petroleum Refining Sector (Draft)	July, 1987
Effluent Monitoring Priority Pollutants List (Draft)	August, 1987
Report on the 1986 Industrial Direct Discharges in Ontario	October, 1987
Estimation of Analytical Method Detection Limits (MDL)	March, 1988
Kraft Mill Effluents in Ontario (Report by the Expert Committee members)	April, 1988
The Public Review of the Draft Effluent Monitoring Regulation for the Petroleum Refining Sector and the Ministry of the Environment's Response to It	July, 1988
Cost Estimates and Implications of the "Effluent Monitoring - General" and "Effluent Monitoring - Petroleum Refining Sector" Regulations for Ontario Petroleum Refineries	July, 1988
Effluent Monitoring Regulations for the Petroleum Sector	July, 1988
Inventory and Critical Review of Laboratory Resources (Final Report)	July, 1988
The Economic and Financial Profile of the Petroleum Refining Sector (Summary Report)	August, 1988
Model Sewer Use By-Law	August, 1988
Controlling Industrial Discharges to Sewers	September, 1988
The Development Document for the Draft Effluent Monitoring Regulation for the Organic Chemical Manufacturing Sector	October, 1988

Report on the 1987 Industrial Direct Discharges in Ontario	October, 1988
Effluent Monitoring Priority Pollutants List-1988 Update	March, 1989
The Development Document for the Effluent Monitoring Regulation for the Metal Casting Sector	January, 1990
Interim Pollution Reduction Strategy for Ontario Kraft Mills	April, 1989
The Development Document for the Effluent Monitoring Regulation for the Electric Power Generation Sector	February, 1990

Copies of these reports are available at the MISA office.

4.1.3.1 Compliance and Enforcement

A number of enforcement options are available under the *Environmental Protection Act* to ensure compliance where an adverse effect on the environment will or is likely to occur.

Legally enforceable Control Orders may be issued to any existing plant under Section 6 of the EPA. Control Orders define tasks and compliance dates by which specific tasks must be completed.

Control Orders may require a facility to perform any of the following:

- limit a discharge;
- install necessary equipment;
- produce a contingency plan and have spill response equipment;
- provide financial assurance;
- repair/remediate damage to the environment; and
- stop operations.

There are federal regulations imposed under the *Fisheries Act* for effluents from the mining, petroleum refining, and pulp and paper sectors as well as the mercury cell chlor-alkali process. As well, the federal Policy for the Management of Fish Habitat, established under this act, has an overall objective of 'no net loss' of habitat with the goals relating to habitat conservation, development, and remediation of damaged habitat. Certificates of Approval (CofA) for sewage works are issued under the *Ontario Water Resources Act*. In the past, the CofA was an approval to install pollution control equipment with the expected effluent quality, used as the basis for design, sometimes shown in the CofA. Recently, new sewage work approvals have begun to include effluent limits which are legally enforceable, since the required performance of the treatment system is explicitly defined.

For non-compliance with legally enforceable limits, the Ministry's approach is to develop an action plan to return the discharger to compliance. Such a plan could include enforcement measures, abatement negotiations or issuance of Control Orders.

For exceedence of guideline limits, regional abatement staff assess whether the exceedence caused or would likely cause impairment to the receiving waters. If so, then enforcement actions may be initiated as for non-compliant sources above. Otherwise, Ministry staff request dischargers to take voluntary abatement measures and/or Ministry staff work together with the company to eliminate the exceedences.

Remedial actions are often complex, involving problem definition, development of appropriate remedial measures, negotiation of abatement plans including public consultation, design, approval, construction and commissioning of works, and may extend over several years in some situations.

Under the EPA, offenses may result in fines to individuals of up to $5,000 plus one year in jail for a first offense, and up to $10,000 plus one year in jail for subsequent offenses. Corporations may receive penalties of up to $50,000 and $100,000 for first and subsequent offenses, respectively.

Only the exceedences of legally enforceable limits in Control Orders, Requirement and Direction, and Certificates of Approval could directly result in prosecutions under existing legislation. The guidelines in and of themselves, are not directly legally enforceable. Consequently, a separate review of guideline limit exceedences is provided.

The Ministry will continue to expect industrial dischargers to meet any numerical limits including guidelines until they are replaced by the technology based requirements of MISA being phased in for major industrial sectors over the next few years.

4.1.4 Non-Point Sources

There are limited controls under the OWRA and EPA for urban and rural/agricultural runoff. No control strategies exist for the treatment of combined sewer overflows (CSOs). However, the province has worked with municipalities to segregate sanitary and storm sewers to reduce CSOs and sewage treatment plant bypasses. The MISA program will consider abatement requirements for CSOs. Stormwater quality management is discussed in Section 4.1.4.4.

Guidelines for snow disposal and de-icing operations in Ontario require that snow dumps be located on land, remote (greater than 600 feet) from surface water, and should not seriously obstruct natural drainage or contaminate groundwater. The bulk use of de-icing compounds, other than salts, is restricted to special circumstances (e.g. airport runways). A program is underway to control and mitigate leachate from salt storage facilities.

Agriculture Canada and the Ontario Ministry of Agriculture and Food have instituted the Soil and Water Environmental Enhancement Program (SWEEP) to educate farmers on new tillage, crop rotation and soil conservation practices, and have provided soil testing services to assist in determining appropriate application rates for fertilizers and lime. Under the *Ontario Environmental Protection Act*, farmers are required to comply with the 1973 Agricultural Code of Practice for Ontario to reduce contaminant loads to receiving streams. The Ontario Ministry of the Environment has restricted application rates, times and contaminant levels in sewage sludges applied to agricultural land (Table 4.6).

Ontario Ministry of Agriculture and Food's Land Stewardship Program provides grants for the adoption of conservation farming practices that will enhance and sustain agricultural production, and improve soil resources and water management by 1) reducing soil erosion and soil compaction, 2) restoring soil organic matter and structure, and 3) minimizing potential for environmental contamination from agricultural practices. The Land Stewardship Program consists of four components: financial assistance, research, education and extension, and program delivery and service.

The Farm Pollution Advisory Committee (FPAC) is comprised of four farmers appointed by the Minister of the Environment under Section 3(1) of the *Environmental Protection Act*. The FPAC's role is to advise the Minister about whether in a specific situation, animal waste is being handled and disposed of in accordance with "normal farming practice", and thereby not impacting the quality of nearby water bodies. This advise is crucial to the Minister due to exemptions in the EPA for agriculture.

4.1.4.1 Shipping

Pleasure crafts are controlled by Ontario's Boating and Marine Regulations, pursuant to the *Environmental Protection Act*. Small boats must be fitted with holding tanks to contain wastewater, which are

Table 4.6 Ontario Metal Criteria for Land Application of Sewage Sludge.*

Metals	Maximum Permissible Concentration (mg/kg solids)
Arsenic	170
Cadmium	34
Cobalt	340
Chromium	2,800
Copper	1,700
Mercury	11
Molybdenum	94
Nickel	420
Lead	1,100
Selenium	34
Zinc	4,200

* These values are for all aerobic sewage sludge and all dried and dewatered anaerobic sewage sludge. Other regulations apply for liquid anaerobic sewage sludge.

emptied by special pumps at marinas. Non-waste water is not regulated under provincial regulations. Commercial shipping activities that may affect water quality are regulated under the *Canada Shipping Act*. These regulations are discussed in Section 4.2.3.1.

The provincial *Dangerous Goods Act* reiterates the measures outlined under the federal *Transportation of Dangerous Goods Act*. Provincial Guidelines for Environmental Protection Measures at Chemical Storage Facilities recommend preventive procedures consistent with those of the Manufacturing Chemists Association. For liquids, this would entail diked containment at a location away from piping and drainage systems, the compatibility of liquids stored in proximity and the use of safety alarms. Gases and volatile liquids are stored more safely in appropriately vented roof tanks with water deluge systems to capture any escaping soluble compounds. All drainage and leakage from storage areas should be collected and treated prior to disposal.

4.1.4.2 Spills

Part IX of the *Environmental Protection Act*, referred to as the "Spills Bill", deals with spills of pollutants into the natural environment from or out of a structure, vehicle or other container, that are abnormal in light of all circumstances, and which cause, or are likely to cause, adverse effects. The "Spills Bill" establishes notification requirements, responsibilities and compensation mechanisms, in addition to other factors. The Ontario Spills Action Centre, whose origin was spawned by the "Spills Bill", coordinates the Ministry's response network, working closely with the Canadian Coast Guard, police and fire departments, and other reporting centres, as well as downstream water users in Ontario and Michigan.

In the event of a spill OMOE spills response protocol involves site investigation, sampling and if required, spill modelling in order to determine downstream impacts. In addition, the Chippewa County medical officer of health is notified.

4.1.4.3 Sediment Quality

The quality of sediments is assessed against contaminant concentrations established in the 1978 Revised Guidelines for Open Water Disposal of Dredged Spoils (Table 4.7). The OMOE allows open water disposal of dredged materials with contaminant levels less than established guidelines, providing existing water uses are not affected. Any other suspected contaminants in the sediments are evaluated on a case-by-case basis.

Contaminated sediments constitute a significant environmental concern in the Great Lakes Basin, and existing guidelines are under review by most agencies. Special advisory groups, such as the Polluted Sediment Subcommittee under the Canada-Ontario Agreement, have been established to review sediment guidelines and assessment criteria, to evaluate dredging activities and in-place remedial options, and to provide expert advice on infilling practices. Under the EPA the OMOE can order the removal of contaminated sediments.

Biologically-based Provincial Sediment Quality Guidelines for contaminant concentrations in sediments are currently under development. The draft sediment quality guidelines are also presented in Table 4.7 (March 1991 version). They will replace the open water disposal of dredged material guidelines once approved. These guidelines have been designed to address the significance of contaminants in *in-situ* sediment as opposed to the dredged material open water disposal criteria which only incidently provide general guidance on environmental protection. The sediment quality guidelines were developed specifically to protect those aquatic organisms that are directly impacted by contaminated sediment, i.e., benthic organisms. The three levels of ecotoxic effects are:

No Effect Level - level at which no toxic effects have been observed on aquatic organism;
Lowest Effect Level - level of contamination which can be tolerated by the majority of benthic organisms; and
Severe Effect Level - level at which pronounced disturbance of the sediment dwelling community can be expected.

4.1.4.4 Stormwater

The Interim Stormwater Quality Guidelines (Draft) have been developed jointly by the Ontario Ministries of the Environment (OMOE) and Natural Resources (OMNR) to address the need for stormwater quality management in new developments in developing areas in Ontario. These guidelines are consistent with the approach outlined in the Urban Drainage Design Guidelines (1987a). The purposes of these interim guidelines are:

a) To provide guidance to OMOE and OMNR staff in the review of planning documents and development proposals.
b) To provide guidance to OMOE and OMNR staff in the requirements, evaluation and approval of stormwater management facilities for water quality control for developments proposed under the *Planning Act*.
c) To provide municipalities with OMOE's information requirements for the review of planning documents and planning proposals for stormwater management facilities for stormwater quality control for new developments.
d) To provide guidance to proponents for stormwater management for water quality control.

The Interim Stormwater Quality Guidelines are intended to be reviewed and updated on an ongoing basis. Offices of the OMOE and OMNR request and review quality components of stormwater management proposals for new development under the *Planning Act*. OMOE has the legislative authority to review and approve stormwater treatment works under Section 24 of the *Ontario Water Resources Act*.

The Water Management Goals, Policies and Implementation Procedures of the Ministry of the Environment (Ministry of the Environment, 1984) require conservation and remedial measures for the control of nonpoint sources such as stormwater discharges if they are shown to cause or contribute significantly to violations of the Provincial Water Quality Objectives.

Table 4.7 Ontario MOE Guidelines for Dredged Material Disposal in Open Water and the draft Provincial Sediment Quality Guidelines (mg/kg, unless otherwise noted).

Parameter	Ontario MOE Dredged Material Disposal Guidelines	Provincial Sediment Quality Guidelines[*]		
		No Effect Level	Lowest Effect Level	Severe Effect Level[†]
Total Phosphorus	1000	-	600	2000
Total Kjeldahl Nitrogen	2000	-	550	4800
Ammonia	100	-	-	-
Volatile Solids (Loss on Ignition)	60,000	-	-	-
Oil & Grease	1,500	-	-	-
Arsenic	8	-	6	33
Cadmium	1	-	0.6	10
Chromium	25	-	26	110
Cobalt	50	-	-	-
Copper	25	-	16	110
Cyanide	0.1	-	-	-
Iron	10,000	-	2%	4%
Lead	50	-	31	250
Manganese	-	-	460	1100
Mercury	0.3	-	0.2	2
Nickel	25	-	16	75
Silver	0.5	-	-	-
Zinc	100	-	120	820
Total PCBs	0.05	0.01	0.07	530
Total PAHs	-	(2)	(11,000)	
Hexachlorobenzene	-	0.01	0.02	24
Aldrin	-	-	0.002	8
BHC	-	-	0.003	12
α-BHC	-	-	0.006	10
-BHC	-	-	0.005	21
τ-BHC	-	0.0002	(0.003)[a]	(1)[b]
Chlordane	-	0.005	0.007	6
Total DDT	-	-	0.007	12
op+pp-DDT	-	-	0.008	71
pp-DDD	-	-	0.008	6
pp-DDE	-	-	0.005	19

Table 4.7 (cont'd)

Parameter	Ontario MOE Dredged Material Disposal Guidelines	Provincial Sediment Quality Guidelines*		
		No Effect Level	Lowest Effect Level	Severe Effect Level†
Dieldrin	-	0.0006	0.002	91
Endrin	-	0.0005	0.003	130
Heptachlor	-	0.0003	-	-
Heptachlor Epoxide	-	-	0.005[a]	5[b]
Mirex	-	-	0.007	130
Total Organic Carbon (TOC)	-	-	1%	10%

Note: Lowest Effect Levels and Severe Effect Levels for organic parameters are based on the 5th and 95th percentiles, respectively of the Screening Level Concentration (SLC) unless noted otherwise: [a] -10% SLC. [b] -90% SLC.

() denotes tentative guidelines.

\- no guideline developed.

* values < 10 have been rounded to one significant digit, values greater than 10 have been rounded to two significant digits.

† Numbers in this column (organic parameters only) are to be converted to bulk sediment values by multiplying by the actual TOC concentration of the sediments (to an maximum of 10%), e.g., analysis of a sediment sample gave a PCB value of 30 ppm and a TOC of 5%. The value for PCB in the Severe Effects column is first converted to a bulk sediment value for a sediment with 5% TOC by multiplying 530 X 0.05 = 26.5 ppm as the Severe Effect Level guidelines for that sediment. The measured value of 30 ppm is then compared with this bulk sediment value and is found to exceed the guideline.

The interim stormwater guidelines are applicable to any new development in developing areas reviewed under the *Planning Act*. Application of the guidelines will depend on the sensitivity of the waterbody that the stormwater is being discharged to. These guidelines could also provide direction in the review of undertakings subject to the *Environmental Assessment Act*, other legislation or other agency programs.

The development criteria contained in the Interim Stormwater Quality Control Guidelines can be implemented within legislative, policy and administrative procedures already available to the two ministries. Therefore, it represents no new policy initiatives or development design techniques, rather, it formalizes how established design and planning tools can be applied and how the two ministries can coordinate their activities and effectively relate to other agencies.

Related Programs and Studies

The Ontario Urban Drainage Management Program (UDMP) is designed to encourage good drainage planning and apply good practices in stormwater management, including preparation of Watershed Plans, Master Drainage Plans, and Stormwater Management Plans; major and minor drainage systems in design, and erosion and sediment control during construction. Two documents have been released by the Ontario Urban Drainage Implementation Committee in support of the UDMP: Urban Drainage Design Guidelines, 1987, and Guidelines on Erosion and Sediment Control for Urban Construction Sites, 1987.

The UDMP deals mainly with stormwater quantities. Control of stormwater pollution in new developments is envisioned mainly as erosion and sediment control during construction. The UDMP is voluntary at this time. This position will be re-evaluated after sufficient experience is gained.

OMOE's Pollution Control Planning (PCP) Program funds the abatement of pollution in existing urban areas. This PCP Program is carried out on an "as needed basis", separately from urban drainage planning such as Master Drainage and Stormwater Management Plans. The PCP Program does; however, provide input to urban drainage planning activities where multi-source water quality problems (especially wet weather sources) exist.

4.1.5 Wetlands and Shorelands

Physical alterations to Ontario Crown lake, river and stream beds and adjacent to shorelands are regulated by the *Public Lands Act* (1980). This act provides for a work permit and associated review process which, among other things, allows authorities to ensure critical fish and wildlife habitat will not be destroyed or harmed by the work proposed. Fisheries habitat such as spawning, nursery and feeding sites, as well as migration routes, is afforded more direct protection by means of the *Fisheries Act*. This is a federal statute which is enforced by both provincial and federal agencies.

Ontario provincial agencies and the federal government have entered into a Habitat Management Agreement whereby fish habitat, which includes many wetland areas, is to be protected and opportunities for rehabilitation are considered where feasible. A draft wetlands policy is currently under review and is expected to be in place soon. It will give special recognition to the values provided by the most significant classes of wetlands in the province.

4.1.6 Solid, Liquid & Hazardous Waste Controls

Solid and hazardous waste programs are implemented by the provincial government mainly under the *Environmental Protection Act*. The EPA Waste Management-General Regulations describe the classification and approval of waste disposal sites and waste management systems. Standards for the location, maintenance and operation of a landfill site are outlined, including measures to be taken for the collection and treatment of contaminants for the prevention of water pollution. These include locating the landfill site above, or isolated from, the maximum ground water level to protect the aquifer, and allowing sufficient distance from water sources to prevent contamination, unless all leachate is collected and treated. The implementation of the Waste Management General Regulations and related policies are summarized in "The Incorporation of the Reasonable Use Concept into the Ground Water Management Activities of the Ministry of the Environment." In addition to landfill record-keeping requirements, an expanded manifest system was recently implemented under EPA Regulation 309 to ensure the registration of wastes by generators, and proper handling, shipping and disposal by carriers and receivers. The Hauled Liquid Industrial Waste Disposal Sites Regulations (EPA Regulation 808) prescribes standards for the operation and maintenance of all Ministry-approved industrial sites. One requirement is that ground water and surface water quality in and around the site shall be regularly monitored.

The Guidelines for the Treatment and Disposal of Liquid Industrial Wastes in Ontario applies to Ministry-approved waste treatment and disposal processes or sites (except those covered by other regulations or guidelines). These Guidelines list various industrial wastes and recommend a corresponding treatment and disposal process.

The provincial Waste Management PCB Regulations require owners or generators of PCB wastes to keep records regarding the waste's nature, quantity, storage method and location on-site (or transportation offsite), while awaiting final resolution of the waste. Standards for the location, maintenance and operation of mobile PCB destruction facility waste disposal sites are included in the Mobile PCB Destruction Facilities

Regulation. Two such companies operate in Ontario. Maximum point of impingement levels are imposed on air emissions of PCBs, chlorinated dibenzodioxins, and chlorinated dibenzofurans. All solid wastes generated must be disposed of at a certified waste disposal site.

4.1.7 Pesticides

The provincial *Pesticides Act* (1980) prohibits, in general, the discharge or emission of pesticides that would cause or be likely to cause damage to the environment, animal or plant life, or human health greater than the impairment that would necessarily result from the proper use of the pesticide. A license to carry out exterminations and other requirements such as application methods, permits, safety precautions, and use restrictions for specific pesticides are outlined in the Pesticides (General) Regulations.

The only agricultural pesticide program is the Integrated Pest Management Program, administered by OMAF, which provides advice on pesticide use to farmers. This program is not directed at environmental or water quality protection.

4.1.8 Air Quality

Air quality in Ontario is regulated under Regulation 308 of the *Ontario Environmental Protection Act*. Under this regulation, the Ministry of Environment may prepare an "Air Pollution Index" to express the relative levels of air pollution. As an index level is approached or exceeded, the Ministry of Environment, in consultation with the Ministry of Health, may order curtailment of the operation of sources of air pollution. The Regulation also identifies the maximum concentration of contaminants at a point of impingement from a source of contaminant, other than a motor vehicle. The maximum concentrations are outlined in Appendix 4.2.

Monitoring is most extensive for ozone, sulphur dioxide, carbon monoxide, total suspended particles and particle-bound lead. Less extensive monitoring is conducted for oxides of nitrogen, hydrocarbons, reduced sulphur and other constituents of the particulate matter. Ontario MOE also conducts ambient air quality monitoring in Sarnia, Windsor and Sault Ste. Marie, measuring similar parameters as above. A report is issued annually.

The Ontario MOE Air Resources Branch conducts studies of long range transportation and deposition to the Great Lakes, specifically for toxic contaminants. There is one permanent air monitoring station, near Lake Huron, involved in this study area.

4.1.9 Fish Consumption Advisories

Ontario has established concentration limits for boneless skinless fillets of dorsal muscle based on guidance from Health and Welfare Canada and the *Federal Food & Drug Act* (Table 4.8). Ontario has used these limits to establish restricted consumption guidelines. Fish contaminant data is not generally evaluated on the basis of mean or average contaminant values. Rather a geometric regression analysis of length versus contaminant concentration is done to determine at what size a particular sample collection analyzed individual may exceed a particular Health and Welfare Canada criterion. At the size where the concentration exceeds the criterion, restricted consumption is advised (or no consumption, in the cases of women of child-bearing age and children under 15 years of age) for fish in that size category and above. Mercury also has a "No Consumption" guideline, above which no consumption is advised for all populations. Ontario publishes its consumption advisories for various fish species, sizes and locations annually in "Guide to Eating Ontario Sport Fish".

Table 4.8 Canadian Legal Limits for contaminants in commercial fish (mg/kg).

Parameter	Concentration in Edible Portion H&WC*
Total Mercury	0.5
PCBs	2.0
Dieldrin	0.1†
DDT + metabolites	5.0
Endrin	0.1†
Heptachlor/H. epoxide	0.1†
Lindane	0.1†
Mirex	0.1
2,3,7,8-TCDD	0.000020‡
Lead	1.0 §
Toxaphene	0.1†
Chlordane	0.1
Malathion	0.1
Parathion	0.1

* U.S. EPA. 1989. Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish: A Guidance Manual. September 1989. EPA-503/8-89-002. Washington D.C.

† Legal limit for agricultural chemicals in general.

‡ Currently under review.

§ In areas where lead is considered to be in the organic form.

While there are no Federal guidelines for the levels of copper, nickel, zinc, cadmium, manganese, chromium, arsenic, and selenium in fish, they are usually not detected in trace levels in Ontario sport fish. Based on the guidelines for levels in other food stuffs, there is no need to suggest restrictions on the consumption of fish. This is also the case for hexachlorobenzene.

4.1.10 Drinking Water Objectives

The Ontario Drinking Water Objectives (ODWOs) are used to assess the suitability of surface water supplies for treatment and public consumption. The ODWOs specify that three types of drinking water quality objectives shall be recognized; Maximum Acceptable Concentrations, Interim Maximum Acceptable Concentrations, and Maximum Desirable Concentrations. These are described below. Drinking water quality objectives are provided in Appendix 4.3.

Maximum Acceptable Concentration (MAC)

This term is used for limits above which there are known or suspected adverse health effects. The presence of a substance in drinking water at a level in excess of its maximum acceptable concentration shall be grounds for rejection of the water unless effective treatment is available. The length of time the maximum acceptable concentrations can be exceeded without injury to health will depend on the nature and concentration of the contaminant; however, no drinking water can be permitted to exceed these limits continuously. The MACs are developed under the authority of the *Ontario Water Resources Act*. They are based on known or suspected human health effects and may be made into enforceable standards through inclusion in Certificates of Approval. The proposed *Safe Drinking Water Act*, however, would make them enforceable standards.

Interim Maximum Acceptable Concentration (IMAC)

This term is used to describe limits for substances of current concern with known chronic effects in mammals and for which there are no established maximum acceptable concentrations. Although toxicological, epidemiological and health data are available for such substances the data are subject to public and scientific debate before agreement on a maximum acceptable concentration. The IMAC will generally be a conservative value subject to change as more precise information becomes available. When a substance is detected at a concentration above its IMAC, it will signal the need for more sampling and investigation. Requirements for corrective action will be on a case-by-case basis.

Aesthetic Objectives

This term (formerly 'Maximum Desirable Concentration') is used for limits on substances which, when present at concentrations above the objectives, are either aesthetically objectionable to an appreciable number of consumers or may interfere with good water quality control practices. These limits are not legally enforceable; however, should not be exceeded whenever a more suitable supply or treatment process is, or can be made available at a reasonable cost.

Application of Limits

A water supply system is defined as including the works and auxiliaries for collection, treatment, storage and distribution of the water from the source of supply to the free-flowing outlet of the ultimate consumer.

The limits apply to all water supply systems which provide water for domestic purposes and serve more than five private residences or are capable of supplying water at a rate greater than 0.5 litres per second (OWR/Act, 1980). Although a water supply serving five or fewer private residences is excluded from the application of the limits, it is desirable that the quality of water from these supplies should not be inferior to that supplied to the public in general.

The establishment of a limit should not be regarded as implying approval of the degradation of a high quality supply to the specific level. The limits have been derived from the best information currently available; however, the development of drinking water objectives is an ongoing process. Scientific knowledge of the complex inter-relationships that determine water quality continues to increase, as does the understanding of the physiological effects of the substances present in water. Also, new chemical substances are continually introduced into the environment, many of which may contaminate drinking water supplies. Therefore, it may be necessary to revise the established limits or determine limits for other substances as additional and more significant data become available.

4.1.11 Water Treatment Processes

Water treatment processes may be operationally divided into two categories: conventional and specialized treatment. Conventional treatment is considered to be processes that are commonly used to condition surface and groundwaters. Specialized treatment is used for unusual or uncommon treatment requirements, particularly for the control of specific contaminants such as trace organic chemicals. Components of treatment processes and their modification of water quality are summarized in Table 4.9.

Conventional treatment mostly involves coagulation/flocculation, sedimentation and filtration. The main technologies for specialized treatment include adsorption, air stripping, ion exchange/removal and oxidation.

Table 4.9 Water treatment processes.

Process	Purpose
Aeration	Removal of volatile taste and odour compounds and other dissolved gases (i.e. H_2S, CH_4) Oxygenation and deoxygenation Oxidation (iron)
Presedimentation	Removal of readily settleable particulate matter
Chemical Oxidation	Disinfection, biological control Taste and odour control Oxidation of dissolved metals (iron, manganese) Oxidation of some organic chemicals; colour removal enhancement
Coagulation-flocculation	Destabilization of colloidal material and macro-molecules and agglomeration of settleable or filterable particulates for the removal of turbidity and colour
Sedimentation	Removal of settleable flocculated particulates prior to filtration
Filtration	Removal of particulates, polishing of water through physical and chemical/biological processes Dual chemical-physical filters (iron and manganese removal)
Softening	Reduction in hardness through the removal of calcium and magnesium by precipitation or ion exchange
Carbon Adsorption	Taste and odour control Colour reduction assistance Removal of some organic chemicals including trihalomethane precursors

4.2 CANADA

4.2.1 Environmental Legislation Relevant to the Great Lakes

Under the *Canadian Constitution Act* of 1867, the provinces and territories have been given authority over most natural resources and water quality except on federal property, international issues and in other specific areas of federal jurisdiction. However, the federal government acts in an advisory capacity on many issues by recommending guidelines to the provinces. Table 4.10 lists the significant legislation from which specific environmental regulations and programs are derived.

4.2.2 Point Sources

The *Fisheries Act* is the most significant Federal Statute for the protection of fish habitat from chemical pollution. Promulgated in 1977, the habitat protection provisions of the Act provide for the protection of fish and fish habitat from disruptive and destructive activities. Section 33(2) of the Act provides comprehensive powers to protect fish, fish habitat and human use of fish by prohibiting the discharge of deleterious substances to Canadian Fisheries waters and is legally enforceable when an impact on fish or fish habitat can be shown. A deleterious substance is defined by Section 33(11) as any substance or water that has been processed or changed which, if added to the system, would degrade the quality of the water so that it is rendered deleterious to fish or fish habitat.

Table 4.10 Canadian Environmental Legislation.

Canada Legislation	Media or Activity Addressed												
	A	B	C	D	E	F	G	H	I	J	K	L	M
*Fisheries Act**	1	3	1	1	1	3	3			3			3
Canada Water Act	2	2	3									2	
Canadian Environmental Protection Act	3	3	3	1	1	1	1	2	1		1	2	
(CEPA)*													1
Food and Drug Act	3	3	3								1		
*Canada Shipping Act**	3	3	3			1					1		
Transportation of Dangerous Goods Act							1			3			
(TDGA)						1							
Pest Control Products Act (PCPA)													
Environmental Contaminants Act (repealed)*													

* Significant Act elaborated on in the text.

Key to Codes

A: Ambient Surface Water and Ground Water Quality and Management
B: Sediment Quality and Management
C: Biota Quality, Habitat Management and Habitat Protection
D: Industrial Point Source Discharge Control
E: Municipal Point Source Discharge Control
F: Solid and Hazardous Waste Management
G: Pesticide Manufacture and Management
H: Urban Runoff and Combined Sewer Overflow Management
I: Air Point Source Discharge and Ambient Air Quality Control
J: Agricultural Land Management
K: Spills and Shipping Activities
L: Drinking Water Quality Control and Management
M: Fish Consumption Guidelines or Advisories

1: Legislation is responsible for legally enforceable standards and/or has direct authority over the media or activity.
2: Legislation provides non-enforceable guidance or authority over media or activity.
3: Legislation is not directly applicable to the media or activity, but media/activity may be impacted by execution of its legislative mandate.

Federal effluent regulations and guidelines for various industrial sectors are promulgated under Section 36 of the *Fisheries Act*, and are based on the application of best practicable technology. In general, regulations set national effluent limitations that apply to new and expanded plants, and guidelines set minimum acceptable standards that apply to existing plants. To date, *Fisheries Act* regulations and guidelines have been promulgated for the pulp and paper, mining, petroleum refining, metal finishing, chlor-alkali and mercury sectors. Some of these regulations and guidelines are currently being updated. Only one of these regulations, the Pulp and Paper Effluent Regulations and Guidelines (1991), has applicability to the St. Marys River.

Federal guidelines for effluent quality and wastewater treatment at federal establishments apply to all effluents discharged from landbased establishments under the direct authority of the federal government, excluding vehicles and vessels. These guidelines have been developed and are administered by Environment Canada, and are revised and amended periodically to reflect new developments in technology and changing circumstances. Effluent guidelines for wastewater from federal facilities are to be equal to or more stringent than provincial standards. The guidelines contain both general and specific limits, and apply primarily to domestic-type effluents. General limits describe, qualitatively, the effluent quality (e.g., it should be free from materials harmful to aquatic life). Specific limits set numerical concentrations for conventional pollutants (Table 4.11).

The *Canada Water Act* provides for water quality management authorities under agreement with the province of Ontario. The Canada-Ontario Agreement Respecting Great Lakes Water Quality (COA) covers water quality objectives, monitoring requirements and shared cost programs. This agreement is a public contract between the federal and provincial government in which those governments agree to undertake and coordinate activities within their jurisdiction to fulfil the GLWQA requirements.

All but Section 9 of the *Environmental Contaminants Act* has been repealed and replaced by the *Canadian Environmental Protection Act*, 1988 (CEPA). Under this legislation, the federal government restricts the phosphorus content in detergents to 5 percent by weight (expressed as phosphorous pentoxide) or 2.2 percent by weight (expressed as elemental phosphorous). In addition, the act identifies specific chemicals subject to regulation. Chemicals which are currently prohibited from commercial, manufacturing or processing uses include certain polychlorinated biphenyls (PCBs), dodecachloropentacyclodecane, certain polybrominated biphenyls, chlorofluoro-carbons and polychlorinated terphenyls. In addition, draft regulations have been prepared under this act for pulp and paper mills to prohibit the commercial, manufacturing or processing uses of certain chlorinated dioxins and furans as well as to regulate their maximum concentrations in products and environmental releases. Regulations can also be developed for other chemicals if the chemical is demonstrated to be toxic.

Municipal effluent objectives have been recommended to the provincial governments who, in turn, have established minimum treatment requirements for their municipal facilities by limiting the concentration of total phosphorus in their effluents.

Table 4.11 Canadian and Ontario Effluent Guidelines.

Parameter	Ontario Industrial Effluent Objectives	Canadian Municipal Effluent Objectives
BOD5 (mg/L)	15	20
Suspended Solids (mg/L)	15	25
Oil and Grease (mg/L)	15	15
Ammonia-Nitrogen (mg/L)	10	-
Fecal Coliforms MF/100 ml	-	400
pH SU units	5.5-9.5	6-9
Total Phenols (mg/L)	0.020	0.02
Total Phosphorus (mg/L)	-	1
Total Residual Chlorine (mg/L)	-	0.5
Cadmium (mg/L)	0.001	-
Chromium (mg/L)	1.0	-
Copper (mg/L)	1.0	-
Lead (mg/L)	1.0	-
Mercury (mg/L)	0.001	-
Nickel (mg/L)	1.0	-
Tin (mg/L)	1.0	-
Zinc (mg/L)	1.0	-

4.2.3 Non-Point Sources

The Soil and Water Environmental Enhancement Programme (SWEEP) has been instituted by Agriculture Canada and the Ontario Ministry of Agriculture to educate farmers about new technologies, the benefits of crop rotation, and other soil conservation practices. New agricultural practices such as these are being promoted in an effort to reduce contaminant and nutrient loadings and soil erosion to adjacent surface water.

4.2.3.1 Shipping

The *Canada Shipping Act* controls pollution from ships. Regulations have been passed under this Act directed at shipping activities that may impact water quality, including the control of the discharge of oil, vessel wastes and shipboard wastes. Under these regulations, the vessel may be fitted with a patent sewage treatment plant, which treats sewage to secondary standards, and reduces both suspended solids and the five day biological oxygen demand to 50 mg/L. The alternative requires the vessel to be fitted with a holding tank which must be emptied on shore. In both cases, a 90 percent reduction occurs, and the remaining treated effluent is disinfected.

The protection of the environment and human health from chemical spills during transportation or storage is regulated by both the provincial and federal governments. The *Transportation of Dangerous Goods Act* prescribes safety requirements, standards and safety marks on all means of transport across Canada.

4.2.4 Hazardous Waste Control

Environmental Protection Act, Environment Canada has the authority to control the manufacture, transport, use, disposal, import and export of chemicals and wastes (e.g. PCBs, PCB products and Mirex). The main thrust of this Act is the creation of 1) the Domestic Substances List, which will eventually be a list of all chemicals manufactured and imported to Canada, including toxicity data; 2) the Priority Substances List, which is a list of chemicals under active study by Environment Canada due to concerns over their toxicity; and 3) the Toxic Substances List, which is a list of all chemicals deemed a danger to the environment and for which regulations must be promulgated. The Toxic Substances List includes PCBs, polybrominated biphenyls, chlorofluorocarbons, polychlorinated terphenyls, asbestos, lead, mercury and vinyl chloride.

4.2.5 Pesticides

The principal statute controlling pesticides in Canada is the *Pest Control Products Act* (PCPA) administered by Agriculture Canada. The PCPA sets out regulations regarding the registration, safety and manufacturing of control products to protect human health, and the host plant, animal or article.

Registering pesticides and other control products under the PCPA in Canada provides additional information on registration and labelling requirements such as warning symbols and content description. Under the PCPA, the Minister of Agriculture Canada can establish independent Boards of Inquiry to advise him/her on whether pest control products should be registered. For example, in the recent case of alachlor, a Board of Inquiry was established and then disbanded after making their recommendation to the Minister.

Nonregulatory programs at the federal level include a pest management scheme that may reduce reliance on pesticides. The principal approach to reducing reliance on chemical pest control is known as integrated pest management, and is currently being researched by Agriculture Canada.

4.2.6 Air Quality

The *Canadian Clean Air Act* was repealed and replaced by the Canadian Environmental Protection Act. CEPA regulates atmospheric emissions of toxic chemicals including asbestos (from mines and mills), lead (from secondary smelters), mercury (from chlor-alkali mercury plants) and vinyl chloride (polyvinyl chloride plants). CEPA can also be used to regulate any toxic substance which is released into the air and which creates, or may reasonably be anticipated to create, air pollution in other countries.

Air quality objectives have also been established as a guide in developing programs to reduce the damaging effects of air pollution. The national objectives assist in establishing priorities for reducing contaminant levels and the extent of pollution control needed, provide a uniform yardstick for assessing air quality in all parts of Canada, and indicate the need for and extent of monitoring programs. The Maximum Acceptable Level is intended to provide adequate protection against effects on soil, water, vegetation, materials, animals, visibility, personal comfort and well-being. The Maximum Desirable Level defines long-term goals and provides a basis for an anti-degradation policy in unpolluted areas of the country. The Maximum Tolerable Level denotes concentrations of air contaminants that require abatement without delay to avoid deterioration of air quality to a level that endangers the prevailing Canadian lifestyle or, ultimately, pose substantial risk to public health.

4.2.7 Fish Consumption Advisories

The federal *Food and Drug Act* authorizes Health and Welfare Canada to establish tolerances for chemical substances in fish and fishery products intended for human consumption. These criteria have been adopted by the Province of Ontario, and are discussed in Section 4.1.9.

4.2.8 Great Lakes Water Quality Working Group

A federal interdepartmental Great Lakes Water Quality Working Group has been established to encourage interdepartmental cooperation in government programs which are designed to help restore and secure the chemical, physical and biological integrity of the Great Lakes. More specific objectives of the Working Group include ensuring and preserving an adequate water quality and quantity for use by wildlife, fish and other organisms, and humans.

4.3 MICHIGAN AND UNITED STATES

4.3.1 Water Quality Standards

Existing and future uses of Michigan surface waters are protected under the Michigan Water Resources Commission Act, 1929 PA 245, as amended. The Act, under Sections 2 and 5, provides for the Part 4 Rules of the Water Resources Commission (WRC) which are Michigan's Water Quality Standards (WQS). These Standards (1) establish water quality requirements applicable to the Great Lakes, their connecting waterways, and all other surface waters of the state, (2) protect public health and welfare, (3) enhance and maintain the quality of water, (4) protect the state's natural resources, (5) meet the requirements of the federal Clean Water Act, (6) are consistent with the U.S.-Canada Great Lakes Water Quality Agreement, and (7) are legally enforceable.

The WQS, filed with the Secretary of State on November 14, 1986, were approved by the U.S. EPA pursuant to Section 303 of the Clean Water Act. Therefore, Michigan WQS supersede the U.S. EPA criteria for Michigan surface waters. This discussion focuses on the Michigan WQS. Copies of the Water Resources Commission Act and the Water Quality Standards are available upon request from the Michigan Department of Natural Resources (MDNR), Surface Water Quality Division.

Michigan WQS are currently undergoing a triennial review, as required by the Clean Water Act. No substantive changes to the standards are proposed at this time. Therefore, the following discussion will also be applicable once the new standards are approved. As part of the triennial review, a comparison was made of Michigan's WQS and the Great Lakes Water Quality Agreement (GLWQA) objectives. The WQS were found, overall, to be consistent with the goals and specific objectives of the GLWQA. The report of the comparison is provided in Appendix 4.4.

The Water Quality Standards designate specific uses as a minimum basis for which all Michigan surface waters must be protected. These uses include agricultural, industrial, and public water supply; use by warmwater fish, other indigenous aquatic life, and wildlife; navigation; and partial body contact recreation (e.g. fishing and boating). Additional protection is afforded to waters that are protected for use by coldwater fish; this includes the Great Lakes, their connecting waters (except for the Keweenaw Waterway), and all waters designated by the Michigan Department of Natural Resources (MDNR) as trout streams or trout lakes. All waters of the state are designated for, and shall be protected for, total body contact recreation (e.g. swimming) from May 1 to October 31. The WQS also specify that all waters be protected for the most restrictive of all applicable designated uses. The standards also define parameters and criteria levels necessary to protect a waterbody for its designated uses. Specific WQS are stated which set forth minimum and maximum levels for certain water quality parameters (Table 4.12).

Toxic substances are controlled under a narrative rule (Rule 323.1057) specifying that they shall not be present in Michigan waters at concentrations that are, or may become, injurious to the public health, safety or welfare; plant and animal life; or the designated uses of those waters. Rule 57 is applicable to the 256 chemicals and classes of chemicals listed on the 1984 Michigan Critical Materials Register; the priority pollutants and hazardous chemicals in the Code of Federal Regulations; and any other toxic substances determined by the WRC to be of concern at a specific site.

Specific, allowable levels of toxic substances may be established by the MDNR under Rule 57. Specific guidelines for the development of allowable levels of toxic substances in surface water have been developed and are available upon request from the MDNR, Surface Water Quality Division. Following these guidelines, concentrations of toxic substances in surface water necessary to protect aquatic life, wildlife and human health (life cycle safe and cancer risk) are calculated. The most restrictive concentration is used as the allowable level in surface water. Allowable levels of toxic substances in surface water are given in Table 4.13. Allowable levels for certain toxic substances may be water body specific. For example, the toxicity of some heavy metals is dependent on the hardness of the water. Therefore, allowable levels for those metals are also dependent on water hardness.

Portions of waterbodies can be designated as mixing zones which are defined as areas where point source discharges are mixed with the receiving water. However, there are several requirements that apply to the water quality within the mixing zone. As a minimum restriction, waters may not be acutely toxic to fish or fish food organisms anywhere within the mixing zone. Exposures in mixing zones may not cause deleterious effects to populations of aquatic life or wildlife, and the mixing zone shall not prevent the passage of fish or fish food organisms in a manner which would result in adverse impacts on their immediate or future populations.

The Water Quality Standards are minimally acceptable water quality conditions. Ambient water quality should be equal to or better than the Water Quality Standards 95 percent of the time. Antidegradation requirements exist for waters that have better water quality than the established Water Quality Standards, or that is needed to protect existing uses. The Antidegradation Rule of the WQS states that waters may not be lowered in quality unless it is determined by the WRC that degradation of the these waters will not impair designated uses or be unreasonable and against public interest in view of the existing conditions.

Table 4.12 Summary of Michigan Surface Water Quality Standards.

Parameter	Limit
Turbidity, Color, Oil films, Solids (floating, suspended or settleable), Foams, Deposits	Waters of the state shall not have any of these unnatural physical properties in quantities which are or may become injurious to any designated use.
Total dissolved solids (TDS)	The addition of any dissolved solids shall not exceed concentrations which are or may become injurious to any designated use. In no instance shall they exceed 500 mg/L monthly average or 750 mg/L maximum for any waters of the state.
Chlorides	A maximum of 125 mg/L monthly average is allowed for waters of the state designated as public water supply sources, except for the Great Lakes and their connecting waters where chlorides shall not exceed a 50 mg/L monthly average.
Hydrogen Ion Concentration (pH)	6.5-9.0 in all waters of the state. Any artificially induced variation in natural pH shall remain within this range and shall not exceed 0.5 units of pH.
Taste and Odour	Waters of the state shall contain no taste-producing or odour-producing substances in concentrations which impair or may impair their use for a public, industrial or agricultural water supply source or which impair the palatability of fish.
Toxic Substances	Substance specific as determined by Rule 57. (See text for description, and Table 4-13 for Rule 57(2) levels.)
Radioactive Substances	Standards prescribed by the U.S. Nuclear Regulatory Commission and the U.S. Environmental Protection Agency.
Phosphorus	1.0 mg/L as a maximum monthly average for effluent discharges.
Nutrients	In addition to the maximum phosphorus discharge levels allowed, nutrients shall be limited to the extent necessary to prevent stimulation of growths of aquatic rooted, attached, suspended and floating plants, fungi or bacteria, which are or may become injurious to the designated uses of the waters of the state.
Fecal Coliform	All waters of the state shall contain not more than 200 fecal coliforms per 100 millilitres as determined on the basis of a geometric average of any series of 5 or more consecutive samples taken over not more than a 30-day period. This concentration may be exceeded if such concentration is due to uncontrollable nonpoint sources. The WRC may suspend this limit from November 1 through April 30 upon determining that designated uses will be protected.
Dissolved Oxygen (DO)	A minimum of 7 mg/L in all Great Lakes and connecting waterways, and lakes and streams designated for coldwater fish. In all other waters a minimum of 5 mg/L shall be maintained.
Temperature	No heat load which would warm receiving waters at the edge of the mixing zone more than 3 degrees Fahrenheit above existing natural water temperature for the Great Lakes and their connecting waters; 2 degrees Fahrenheit for coldwater streams; and 5 degrees Fahrenheit for warmwater streams.

Table 4.13 Allowable Levels of Toxic Substances in Surface Water. January 15, 1991 Update.

Chemical Name	Rule 57(2) Allowable Level (µg/L)	Basis*	Comments
Arsenic	184.0	ACV	
Cadmium & Inorganic Salts	0.41	ACV	1
Chromium & Inorganic Salts	48.10	ACV	1
Copper & Inorganic Salts	10.72	ACV	1
Cyanide	4.0	ACV	
Lead & Inorganic Salts	2.88	ACV	1
Nickel & Inorganic Salts	33.34	ACV	1
Selenium & Inorganic Salts	20.0	TLSC	
Silver & Inorganic Salts	0.1	ACV	
Zinc & Inorganic Salts	49.57	ACV	1
Molybdenum	800.0	TLSC	
Paraquat	16.0	ACV	
PCB	0.00002	CRV	2
Formaldehyde	171.0	TLSC	2
DDT	0.0023	CRV	2
Phenol, 2,4-dinitro	9.8	ACV	
Carbon tetrachloride	20.0	CRV	2
Chlordane	0.00053	CRV	
Lindane	0.097	CRV	2
Phenol, 4-chloro-3-methyl	4.4	ACV	
Dieldrin	0.0000315	CRV	
Aniline	4.0	ACV	2
Acetone	500.0	TLSC	
Chloroform	43.0	CRV	2
Hexachloroethane	13.0	CRV	2
Benzene	60.0	TLSC	2
Ethane, 1,1,1-trichloro	117.0	ACV	
Bromomethane	11.0	ACV	
Vinyl chloride	3.1	TLSC	2
Methylene chloride	59.0	ACV	4
Ethylene oxide	56.0	CRV	2
Bromoform	65.0	ACV	
Bromodichloromethane	24.0	TLSC	
Ethylene, 1,1-dichloro	2.6	CRV	2
Heptachlor	0.002	CRV	
Hexachlorocyclopentadiene	0.5	ACV	
Isophorone	860.0	ACV	
Propane, 1,1-dichloro	64.0	CRV	
Ethane, 1,1,2-trichloro	65.0	CRV	2
Trichloroethylene	94.0	ACV	2
Acrylamide	900.0	TLSC	
Ethane, 1,1,2,2-tetrachloro	30.0	TLSC	2
Pentachlorophenol • pH 8.1	20.23	ACV	3
2,4,6-Trichlorophenol	1.5	CRV	2
Dinoseb	0.80	ACV	3
Naphthalene	29.0	ACV	
Benzidine, 3,3-dichloro	0.06	CRV	2, 4
Benzidine	0.0399	CRV	2, 4
Silvex	21.3	HLSC	
Acetic Acid, 2,4-dichlorophenoxy	46.7	ACV	
Benzene, 1,2-dichloro	7.0	ACV	
Phenol, 2-chloro	10.0	ACV	
Ethylbenzene	30.0	ACV	
Styrene	19.0	CRV	2
Benzene, 1,4-dichloro	15.0	CRV	2
Phenol, 4-chloro	9.3	ACV	

Table 4.13 cont'd

Chemical Name	Rule 57(2) Allowable Level ($\mu g/L$)	Basis*	Comments
Ethylene dibromide	1.10	CRV	2, 4
Acrolein	3.0	ACV	
Ethane, 1,2-dichloro	560.0	CRV	2
Acrylonitrile	2.20	CRV	2, 4
Toluene	100.0	ACV	
Chlorobenzene	71.0	ACV	
Phenol	110.0	HLSC	
Bis(2-chloroethyl)ether	4.20	CRV	2
Bis(2-chloroethoxy) methane	4.60	TLSC	
Hexachlorobenzene	0.0018	CRV	2
Benzene, 1,2,4-trichloro	22.0	HLSC	
Phenol, 2,4-dichloro	37.74	ACV	3
1,4-dioxane	2000.0	CRV	2
Chlorodibromomethane	29.0	TLSC	
Tetrachloroethylene	16.0	CRV	2
Ethylene, t-1,2-dichloro	300.0	ACV	
Benzene, 1,3-dichloro	179.0	ACV	
1,2,3,4-Tetrachlorobenzene	0.76	HLSC	
Xylene	59.0	ACV	
Tetra n-butyl ammonium bromide	140.0	TLSC	
2,3,7,8-TCDD	0.000000014	CRV	2, 4
Di-n-propyl formamide	63.0	TLSC	
Mercury, methyl	0.0013	HLSC	
Vanadium	3.73	TLSC	
Ammonia, unionized (coldwater)	20.0	ACV	
Ammonia, unionized (warmwater)	50.0	ACV	
Fluorides (soluble fluorides)	2000.0	TLSC	
Chlorine	6.0	ACV	
Hydrogen sulfide	0.55	ACV	
DBNPA	4.0	ACV	
Chromium, hexavalent	2.0	ACV	
bis(chlorobutyl)ether	60.0	TLSC	

Comment Codes

*ACV = Aquatic Chronic Value
TLSC = Terrestrial Life-cycle Safe Concentration
CRV = Cancer Risk Value
HLSC = Human Life-cycle Safe Concentration

1 Rule 57(2) Level is based on a water hardness of 100 mg/L (as $CaCO_3$).
2 This chemical is regulated as a carcinogen. The Rule 57(2) Level is not necessarily based on its 1 in 100,000 cancer risk value.
3 Rule 57(2) Level is based on a pH of 8.0.
4 Professional Judgement was used - minimum data not available.

The rules also declare that Michigan waters which do not meet the Water Quality Standards shall be improved to meet those Standards. Where the water quality of a certain waterbody does not meet the Water Quality Standards as a result of natural causes or conditions, further reduction of water quality is prohibited.

4.3.1.1 Great Lakes Initiative

The Great Lakes Initiative (GLI) is a joint effort by the U.S. EPA and the eight Great Lakes states to coordinate activities under the Federal Clean Water Act (CWA) to meet the goals of the Governors Great

Lakes Toxic Substances Control Agreement, and to achieve the objectives of the Great Lakes Water Quality Agreement (GLWQA). The GLI will provide a basis for proceeding toward the long term goal of virtual elimination of the discharge of toxic substances to the Great Lakes, and for negotiating Great Lakes programs and water quality objectives with Canada under the GLWQA.

The GLI will develop numeric water quality criteria for a select list of chemicals and a narrative procedure for developing water quality criteria for other chemicals. In both cases, the water quality criteria will include criteria for the protection of human health, wildlife and aquatic life. The GLI will also address issues such as mixing zones, procedures for establishing water quality-based effluent limits in permits, biomonitoring requirements, pollution prevention, and antidegradation. The expected outcome of the GLI is to develop guidance which will be used by the Great Lakes States in reviewing and revising their water quality standards. The projected completion date of the GLI is late 1991.

4.3.2 Point Source Discharge Permits

Effluent requirements for wastewater discharged to Michigan surface waters are established in National Pollutant Discharge Elimination System (NPDES) permits. The NPDES permitting system was established for the entire nation in 1972 by the federal Water Pollution Control Act ("Clean Water Act"; PL 92-500). NPDES permits are required for all point source discharges of pollutants under the Clean Water Act and the Michigan Water Resources Commission Act.

Operation of the NPDES permitting program was delegated to Michigan by the U.S. EPA in October 1973. Effluent limits are required to be at least as stringent as the National effluent guidelines. The Michigan WRC is responsible for issuance or denial of NPDES permits. Effluent requirements and other conditions of a permit are recommended to the WRC by MDNR staff, with assistance from other state departments including the Michigan Department of Public Health. The general responsibility for enforcement of NPDES permit requirements lies with the Department of Natural Resources. The Michigan Department of the Attorney General works with the MDNR as needed to enforce NPDES permit requirements.

The NPDES permits are complex legal documents. Each permit contains the following general parts: specific authorization to discharge wastewater; effluent limitations and monitoring requirements; special conditions applicable to the particular discharge; special conditions applicable for certain general types of programs, such as industrial pretreatment program requirements, management requirements for sludges and other residuals, combined sewer overflow requirements, etc; and the general requirements applicable to all permits, such as what to do in emergency situations, operator certification, permit modification procedures, etc.

The permit is the primary legal document which states under what conditions a discharge is authorized. There are, however, two other areas that are critical to the success of the NPDES program. Prior to permit issuance, water quality studies, surveillance, and monitoring on both the point source discharges and the receiving water body are conducted as needed to determine what limitations should be placed in the permit. This includes both chemical and biological (toxicity tests, biological surveys) characterization. The facility desiring a permit to discharge is required to submit a permit application detailing the treatment process and discharge characteristics (e.g. flow, chemical characteristics). After permit issuance, enforcement followup is needed to ensure compliance with the permit.

One goal of the Clean Water Act is to move toward zero discharge of pollutants by use of treatment technology-based standards, and requiring that minimum receiving Water Quality Standards be achieved. Treatment technology-based discharge standards and effluent limitations based on the Water Quality Standards are determined for a given discharger. Since both must be met, the permits contain the more stringent of the two limits.

Treatment technology based standards are promulgated by the U.S. EPA based on the category of the industrial or municipal facility. National standards have been developed for 26 industrial categories, and involve over 125 toxic pollutants commonly discharged by these industries. Treatment technology-based standards are promulgated for direct discharges to lakes and streams, and for indirect discharges to surface water via sanitary sewer systems. Discharges to storm sewers which do not receive subsequent treatment are considered direct discharges. As treatment technologies improve, these federal standards are expected to become more restrictive in order to progress toward the goal of zero discharge.

Treatment technology-based effluent limitations (TTBELs) are often collectively referred to as the "Effluent Limit Guidelines". When Effluent Limit Guidelines do not exist for a certain discharge, either because none of the industrial categories cover the specific type of operation, or because Effluent Limit Guidelines have not been promulgated for the category yet, treatment technology-based limits must be determined. In this case, the "best professional judgement" of the permit writer is used to determine what the treatment technology-based effluent limits should be for the specific facility. The primary factors that are considered in establishing best professional judgement limits are the type of waste and pollutants, and available technology for a specific discharge. Other factors which may also be considered include costs and benefits of installing a certain treatment technology, and the age of the facility and equipment.

Water quality based effluent limits are determined following the WQS and associated guidelines to ensure that Water Quality Standards are achieved in the receiving waters. The WQS apply at flows greater than the design (drought) flow of the receiving streams. The design flow is the most restrictive of the 12 monthly 95 percent exceedence flows, a statistically-derived, low-flow value that occurs very infrequently. The applicable flows at which Water Quality Standards apply may be different than the 95 percent exceedence flow if the WRC determines that a more restrictive design flow is necessary, or that seasonal design flows may be granted. All Water Quality Standards for conventional pollutants apply after mixing with the design flow. For toxic substances, not more than one-fourth of the receiving water design flow is used for mixing. This is applied to both chemical specific values and biological toxicity endpoints determined through standardized toxicity tests.

Each surface water discharge permit application is reviewed to ensure that appropriate water quality-based control requirements are incorporated in the NPDES permit. All potential contributors (including nonpoint sources) are considered in a wasteload allocation process used by MDNR to establish these water quality-based control requirements. Site specific determinations are made based upon existing data and design conditions for the discharge and the receiving water. Water quality-based effluent limits are proposed when there is the reasonable potential that a point source discharge will cause or contribute to an excursion above any WQS. Water quality based effluent limits are determined by mathematical models used to simulate the substances in the receiving waters. For most toxic pollutants, a simple materials balance is used for calculations. When there are multiple dischargers to a single receiving waterbody, the assimilative capacity must be allocated among them.

Another consideration when issuing permits is "Antibacksliding". This concept has been contained in federal regulations for several years, and was incorporated into the federal Clean Water Act by the 1987 amendments. It is a complex concept which, roughly translated, means that limitations in a previous permit will not be made less stringent when the permit is reissued. Exceptions to the "antibacksliding" rule include when the permittee was unable to achieve the previous permit limits, and when production is increased.

NPDES permits have a maximum life of 5 years. When permits expire, they are reviewed and reissued. A complete cycle of reissuance occurs every 5 years, with approximately 20 percent of the permits being reissued each year. Under Michigan law, an expired permit remains in effect until a new permit is issued or denied.

4.3.2.1 Industrial Pretreatment Program

An important component of the NPDES permitting program is the Industrial Pretreatment Program (IPP). The IPP was developed in recognition of the fact that many industrial operations discharge their wastewater to municipal wastewater treatment plants (WWTP). This industrial wastewater may contain pollutants in concentrations that can interfere with the operations of the WWTP, damage equipment, destroy the bacteria required in the treatment process, pass through the system untreated, or contaminate sludge. To prevent these problems, any Michigan municipality that operates a wastewater treatment plant and receives a discharge from an industrial categorical discharger or an industrial discharger whose discharge could cause any of the following four conditions must develop and implement an industrial pretreatment program:

1. Physical damage to the sewers or the treatment process

2. Inhibition of the WWTP processes

3. Pass-through of pollutants which could cause problems in the receiving stream or result in an NPDES permit violation

4. Accumulation of pollutants in the sludge which could cause problems during its disposal

The IPP contains details as to how the industrial wastewater will be treated prior to discharge to the municipal collection system, establishes local limits and outlines monitoring and compliance requirements. The industrial discharger must also comply with applicable federal treatment technology-based limitations.

The municipality that operates the WWTP is responsible for developing, implementing and enforcing the local IPP. The IPPs are reviewed by the municipality on an annual basis to ensure that compliance with all applicable policies and regulations is maintained. The State reviews and approves the local IPP in accordance with established State and federal IPP regulations. The State functions in an "oversight" role to the local IPP Control Authority, and the U.S. EPA functions in an "oversight" role to the State. An NPDES permit is issued to the municipality for its discharge to the surface water.

4.3.2.2 Combined Sewer Overflows

Combined sewer overflows (CSOs) constitute a serious environmental concern because they constitute a discharge of raw sewage and pose public health concerns. NPDES permits are required for all CSOs. The permits contain date certain schedules for development of CSO corrective programs. The corrective program established in the NPDES permit is a phased approach intended to provide flexibility for individual communities to develop site-specific corrective programs.

Phase I of the CSO corrective program requires operational improvements of the existing system to minimize overflows, sampling and other monitoring requirements to establish a strong database on the existing system, and construction of interim CSO control projects where feasible. Under Phase I, all CSO communities are required to notify the MDNR when there is a discharge of raw sewage to surface waters from CSOs. The MDNR will notify the local public health agency when appropriate. The health agency will issue appropriate advisories. Phase I also requires development of a final program to eliminate or adequately treat CSOs. The final program must also contain a fixed-date schedule to achieve the maximum feasible progress in accomplishing these corrections, taking into account technical and economic considerations.

Phase II is the implementation of the final program under subsequent NPDES permits. The schedule developed under Phase I will be incorporated into the NPDES permit, and the permittee required to proceed with implementation. The permits require that final programs provide for elimination or adequate treatment of CSOs. This will be accomplished on a case-by-case basis with professional staff of the Department working closely with municipalities to define appropriate corrective programs.

4.3.2.3 Compliance and Enforcement

NPDES permits are required under the Clean Water Act and the Michigan Water Resources Commission Act for all point source discharges to surface waters of the State. Any violation of a permit condition, compliance schedule or effluent limit specified in the permit, or a point source discharge to surface water without a permit is a violation of the Clean Water Act and the Michigan Water Resources Commission Act. Such violations of the Acts may be subject to civil and/or criminal action for injunction relief, substantial monetary penalties, and reimbursement for environmental damages.

A permit violation may be detected by the MDNR through routine review of compliance schedules and discharge monitoring reports (DMR) prepared by the permittee, and various types of inspections by MDNR staff. Violations may also be directly reported to MDNR. Upon recognition of a permit violation or a violation of related sections of the CWA or the Michigan Water Resources Commission Act, an appropriate compliance/enforcement action is taken. The compliance/enforcement response will be timely, and appropriate for the nature and severity of the violation.

The MDNR is developing an Enforcement Management System (EMS) to assure that all dischargers are treated fairly, and to consistently enforce the NPDES program as required by the Clean Water Act and the Michigan Water Resources Commission Act. The EMS is a tool to assist professional staff in assuring that timely and appropriate enforcement actions are taken. Guidance is provided in the EMS to assist the state in assessing the magnitude and severity of the violation, and a range of enforcement responses that would be appropriate for the violation. The EMS also establishes a system for identifying priorities and directing the flow of enforcement actions based on these priorities and available resources. The measure of effectiveness of an enforcement response is whether and how expeditiously the noncompliant source is returned to compliance.

4.3.2.4 Stormwater

The federal Clean Water Act as amended in February 1987 contains language which specifically addresses the regulation of stormwater discharges (Section 405). The Act specifies that stormwater discharges will be regulated through the NPDES permit program.

The amendment states, in part, that no stormwater permits shall be required prior to October 1, 1992, except for the following: (1) currently permitted stormwater outfalls; (2) stormwater outfalls from industrial plant sites; (3) municipal storm sewer systems serving more than 250,000 population; (4) municipal storm sewer systems serving between 100,000 and 250,000 population; and (5) any point source of stormwater causing water quality violations.

The Clean Water Act, as amended, provides specific dates for U.S. EPA action regarding regulation development for several of these excepted categories. The U.S. EPA published the final regulations concerning stormwater discharges on November 16, 1990. The regulations defined what facilities would be considered industrial stormwater dischargers and established November 16, 1991 as the date by which these facilities must apply for a stormwater discharge permit. The regulations also established a two part application process for municipalities. Part I for municipalities with populations greater than 250,000 is due November 16, 1991 and part II is due November 16, 1992. For municipalities with populations between 100,000 and 250,000, part I is due on May 18, 1992 and part II on May 17, 1993.

The regulations establish application requirements that for industrial facilities include sampling, topographic maps, impervious surface are estimates and spill history. Applications for municipalities covered by the regulations will include sampling, topographic maps and legal authority of the municipality.

Industrial permits will contain technology and water quality-based requirements. Municipal permits will require the development and implementation of comprehensive stormwater management programs to identify and eliminate illicit discharges to storm sewer and to reduce the discharge of pollutants in stormwater to the maximum extent practicable. Compliance with stormwater permits will be required three years after permit issuance.

4.3.3 Critical Materials and Wastewater Report

A Critical Materials and Wastewater Report must be filed annually with the MDNR by all businesses that discharge wastewater to lagoons, deep wells, the surface of the ground, surface waters, septic tanks, or municipal sewer systems according to the Michigan Water Resources Commission Act. The types of wastewater that must be reported are process water, non-contact cooling water, condenser water, commercial laundry and commercial car wash water. Sanitary wastewater which is discharged to any system other than a municipal sewer or septic tank must also be reported.

The Critical Materials and Wastewater Report sets forth the nature of the business, a list of materials used in or incidental to its manufacturing process, including by-products and waste products, and the estimated volume of wastewater discharged. The materials which must be reported appear on the Critical Materials Register (CMR) as compiled by the MDNR with the advice of a technical advisory committee. The most recent CMR, published October 1, 1988, contains 284 chemicals. The information provided in the report may be used for purposes of pollution control including the determination of parameters to be limited by the NPDES permit.

4.3.4 Nonpoint Sources

The regulation and control of nonpoint sources of pollution in Michigan is the responsibility of a number of state, federal and local agencies, under a variety of programs and legislative directives. Until recently, however, the state lacked a comprehensive, coordinated plan to address nonpoint sources of pollution.

In November 1988, Michigan submitted a four year management plan to the U.S. EPA to address pollution problems caused by nonpoint sources. This management plan, and an assessment of the extent of surface and groundwater contamination due to nonpoint sources (also submitted in November 1988), are required under Section 319 of the Clean Water Act of 1987.

Michigan's Nonpoint Source Management Plan and Assessment Report have been approved by EPA. The Management Plan meets the requirements of the Clean Water Act and qualifies Michigan for federal funding to reduce nonpoint source pollution. Michigan received 1.3 million dollars through Section 319 of the Clean Water Act in Fiscal Year 1990. These funds are being used to implement programs in the Nonpoint Source Management Plan.

Solving nonpoint source pollution problems in Michigan will require the implementation of abatement programs through the cooperative efforts of federal, state and local agencies. Nonpoint source program implementation can occur on either a statewide or watershed basis. One of Michigan's priorities is to emphasize implementation of nonpoint source programs on a watershed basis. Approximately 30 watershed projects are either in the planning or implementation phases throughout the state. A number of statewide programs including development of best management practices, hydrologic analysis, construction site erosion control, technical assistance and information/education programs are underway.

4.3.4.1 Erosion

Soil erosion from construction sites is regulated through the Soil Erosion and Sedimentation Control Act, 1972 PA 347. The Act requires permits for all earth changing activities within 500 feet of a lake or stream, or that are likely to disturb an acre or more of land area. The program is administered by the Department of Natural Resources through local designated enforcement agencies.

Agricultural soil erosion is controlled through the use of conservation practices on farms. The Soil Conservation Service and local Soil Conservation Districts assist landowners in developing conservation practices for their property.

4.3.4.2 Spills

The prevention of and response to spills of oil and polluting materials (salt and any material listed on the Critical Materials Register, in solid or liquid form) to waters of the state are addressed in the Part 5 Rules of the Michigan Water Resources Commission Act, as amended. These rules require Pollution Incident Prevention Plans for spills prevention and cleanup for oil storage facilities and facilities that store, handle, discharge, manufacture, receive or process polluting materials. The rules also require that spill containment equipment and adequate personnel be available at sites where oil is on-loaded or off-loaded through a conduit to a vessel on the waters, and at sites adjacent to a watercourse where oil is stored and handled. Further, the rules specify that adequate surveillance be maintained at all times such that a spill can be immediately detected. When a spill is detected, the rules require immediate response. Under these rules, storage and use areas for oil, salt, and other polluting materials must be adequately diked or contained to prevent escape of spilled materials to groundwater and surface water both directly and indirectly (e.g. through sewers and drains). If a spill occurs from a vessel or a facility, a report must be filed with the WRC outlining the cause, discovery, and actions taken to remove the spilled material from the water.

The Oil and Gas Act, PA 61 requires operation of production and disposal wells in such a manner as to prevent the escape of oil, gas, saltwater, brine or oil field wastes which would pollute, damage or destroy freshwater resources.

The MDNR operates a Pollution Emergency Alert System (PEAS). A toll free telephone line (1-800-292-4706) is maintained for the reporting of suspected pollution incidences. MDNR staff investigate and respond to emergency spill occurrences, and coordinate actions with other agencies. A spill of any quantity of any material is reportable under PEAS.

There are several federal Acts and regulations that pertain to spills prevention and response. Federal regulations under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) identify "hazardous substances", notification requirements in the event of a spill and repotable quantities. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) established under CERCLA concerns the release of oil and hazardous materials into navigable waters. The Clean Water Act also prohibits the discharge of oil in harmful amounts, and requires owners of facilities which present a threat of an oil release to surface water to prepare a Spill Prevention Control and Countermeasure (SPCC) plan. The Solid Waste Disposal Act requires transporters to take appropriate action, and to notify the National Response Centre in the event of a spill. The Emergency Planning and Community Right-to-Know Act of 1986 requires that any facility that produces, uses or stores chemicals regulated under this Act participate in emergency planning procedures for spills. Cleanup policy for PCB spills is contained in the Toxic Substances Control Act.

In the event of an unauthorized release of pollutants to the U.S. waters of the Great Lakes or connecting channels, the U.S. Coast Guard would have the lead responsibility in investigating and responding to the incident. Michigan and Ontario have established an emergency notification protocol to be used in the event of an accidental release to the water or air that may have transboundary impacts. This protocol is discussed in Section 4.5.

4.3.4.3 Ballast Water Exchange

The exchange of ballast water from commercial ships has not been regulated as of this writing. However, the need for such regulation has been recognized due to nuisance conditions caused by the unintentional introduction of exotic aquatic species such as the spiny water flea (*Bythotrephes cederstroemi*) and ruffe (*Gymnocephalus cernua*), and more recently the zebra mussel, via the discharge of ballast water from commercial ships. In March, 1990 proposed legislation was introduced which would initiate a national ballast exchange program, and coordinate and manage regulatory programs for the control of aquatic nuisance species. The draft legislation would institute a voluntary ballast exchange program for two years, after which the program would become mandatory for the Great Lakes. The proposed legislation is expected to be passed in 1990 (S2244, Non-indigenous Aquatic Nuisance Act, and HR 5390, Aquatic Nuisance Prevention and Control Act).

4.3.4.4 Contaminated Sediments

Chemical contamination of freshwater sediments has the potential to adversely affect aquatic life. However, there are, as of this writing, no federal or state sediment quality standards, or guidelines on how to identify sediments that may be detrimental to aquatic life or to assess the severity of the effect. The U.S. EPA is currently investigating several approaches to developing sediment quality criteria (e.g. equilibrium partitioning, apparent effects threshold, tissue residue). Draft criteria have not yet been proposed. The U.S. EPA's Interim Guidelines for the Disposal of Great Lakes Harbour Sediments" of 1977 have been used as a yardstick of contamination. The guidelines are not biologically based, however, and are not indicative of potential effect levels.

Assessing the effects of chemical contamination on aquatic life is complicated by the many variables that affect the toxicity and availability of the contaminants. Therefore, the state is pursuing an assessment protocol that includes a combination of biological field surveys, chemical and physical analyses of sediments, and sediment toxicity tests. MDNR currently conducts biological field surveys, and chemical and (limited) physical analyses of sediments. Work is underway at the MDNR Aquatic Toxicity Evaluation Laboratory (ATEL) to develop and validate procedures for conducting sediment toxicity tests and culturing the required test organisms. ATEL staff is focusing on a solid phase chronic toxicity test with *Chironomus tentans*, an interstitial acute toxicity test with *Daphnia magna* and an interstitial chronic test with *Ceriodaphnia dubia*.

A great deal of information is still required on how to interpret the results of laboratory tests with respect to instream responses, and how to integrate results of the various investigations to determine whether a sediment related problem exists. There are many ongoing efforts in both the regulatory and scientific communities to answer these questions, and Michigan has taken an active interest in a number of them. Probably the most comprehensive of these efforts is the Assessment and Remediation of Contaminated Sediments (ARCS) Program which is administered by the U.S. EPA Great Lakes National Program Office (GLNPO). This is a five year study and demonstration project relating to the control and removal of toxic substances from the Great Lakes. The program was authorized in Section 118 (c)(3) of the Clean Water Act as amended in 1987. The primary objective of the ARCS program is to develop guidance on the assessment of contaminated sediment problems and the selection and implementation of remedial actions. Guidance documents and case study final reports are expected to be completed by October 1993.

4.3.5 Navigational Dredging and Sediment Disposal

Dredging projects in Michigan are evaluated by MDNR and the Michigan Department of Transportation following the International Joint Commission (IJC) Guidelines presented in "Guidelines and Register for

Evaluation of Great Lakes Dredging Projects," Report of the Dredging Subcommittee, January 1982 and the U.S. EPA "Interim Guidelines for the Disposal of Great Lakes Harbour Sediment" of 1977. All dredging projects proposed in Michigan are subject to review and certification under Sections 401(a) and 404(t) of the Federal Clean Water Act, PL 92-500. Through the certification process Michigan addresses water quality impacts which may occur during the proposed dredging and disposal, impacts to fish and wildlife, recreational use concerns and scheduling of the proposed operation.

Water quality concerns may also be addressed under Rule 92 of Michigan's Water Quality Standards. This rule provides that the Water Resources Commission may determine that a dredging activity results in unacceptable impacts on designated uses, and that the Water Quality Standards are applicable during and subsequent to the dredging activity. In these cases, the "401 water quality certification", issued under Section 401 of the Clean Water Act, would reflect any restrictions on the dredging and/or disposal operation. Acting under the authority of Rule 92, the Commission determined that the use of overflow dredging in areas with contaminated sediments (not suitable for open water disposal due to contamination) results in unacceptable impacts on designated uses. Each dredging project where the use of a hopper dredge is proposed is evaluated to determine whether the use of hopper overflow should be prohibited due to sediment contamination.

Dredging permits and 401 Water Quality Certifications may also be required under the Inland Lakes and Streams Act, 1972 PA 346, and the Great Lakes Submerged Lands Act, 1955 PA 247, as amended. All 346/247 permit applications are reviewed with respect to existing sediment contaminant data, and all sites are visited by MDNR personnel regardless of the degree of contamination. Projects proposed in areas with known sediment contamination are reviewed by the MDNR Surface Water Quality Division. Sediment sampling and analysis and/or project modification may be required prior to permit issuance.

The disposal method for dredged sediment is determined following an evaluation of the sediment type, contaminant type and concentration, potential beneficial uses of the material to be dredged, and availability of disposal sites. The U.S. EPA Interim Guidelines for the Disposal of Great Lakes Harbour Sediment, 1977 (Table 4.14) are used as a preliminary indicator as whether the sediments are suitable for open water disposal, or require confinement. Dredged sediments may be suitable for various types of upland disposal depending on the presence of leachable substances and the hazard to the environment. The Solid Waste Management Act, 1978 PA 64, as amended, and the Michigan Environmental Response Act, 1982 PA 307, as amended, and the administrative rules adopted pursuant to these Acts govern upland disposal options.

The Michigan Hazardous Waste Regulations, under the Hazardous Waste Management Act, 1979 PA 64, as amended, and 40 CFR 261 (1986) may be applied to sediments when disposal in a landfill is proposed. Under these regulations, the person(s) doing the dredging may be requested to conduct an extraction procedure toxicity (EP toxicity) and/or the toxicity character leaching procedure (TCLP) to determine if the material is "hazardous". If the material is classified as "hazardous" under the Resource Conservation and Recovery Act (PL 94-586), disposal in a licensed hazardous waste landfill is required.

4.3.6 Wetlands and Shorelines

Wetlands protection and management in Michigan is governed by ten state and two federal statutes that include a variety of specific protection and permitting programs. The state statutes are listed and briefly described in Table 4.15. The two federal statutes, the Clean Water Act of 1972 and the Rivers and Harbours Act of 1899, deal mainly with navigation issues. The Clean Water Act regulates the discharge of dredged or other fill material into navigable waters and their adjacent wetlands. The U.S. EPA is currently developing a Great Lakes Basin wetlands strategy to guide the State Federal jurisdictions on the protection and management of wetlands.

The most recent and comprehensive of the state laws is the Wetland Protection Act, 1979 PA 203. This act provides for the preservation, management, protection and use of wetlands; requires permits to alter

Table 4.14 U.S. EPA Interim Guidelines for the Disposal of Great Lakes Harbor Sediments, 1977.

Parameter	Nonpolluted	Moderately Polluted	Heavily Polluted
Volatile Solids	5%	5% - 8%	8%
COD	40,000	40,000 - 80,000	80,000
TKN	1,000	1,000 - 2,000	2,000
Oil & Grease (Hexane Solubles)	1,000	1,000 - 2,000	2,000
Lead	40	40 - 60	60
Zinc	90	90 - 200	200
Ammonia	75	75 - 200	200
Cyanide	0.10	0.10 - 0.25	0.25
Phosphorus	420	420 - 650	650
Iron	17,000	17,000 - 25,000	25,000
Nickel	20	20 - 50	50
Manganese	300	300 - 500	500
Arsenic	3	3 - 8	8
Cadmium	*	*	6
Chromium	25	25 - 75	75
Barium	20	20 - 60	60
Copper	25	25 - 50	50
Mercury			1
Total PCB**		1 - 10	10

Note: all values in mg/kg dry weight unless otherwise noted.
* Lower values not determined.
** Pollutional classification of sediments with total PCB concentration between 1.0 and 10.0 mg/kg dry weight determined on case-by-case basis.

wetlands; and provides penalties for illegal wetland alteration. Act 203 established a state policy to protect the public against the loss of wetlands and make explicit determinations on the benefits wetlands provide. It also established a permit program to regulate some activities in wetlands that are above the ordinary high water marks of lakes and streams. Additionally, Act 203 explicitly authorized more stringent and broader regulation of wetlands by local governments, and set up a cooperative process for the sharing of information and expertise between the MDNR and local governments.

Activities in wetlands contiguous to waterbodies are regulated without regard to the size of the wetland because of the close relationship these areas have to surface waters. Non-contiguous wetlands, however, are regulated by permit only if they are greater than five acres in size. In counties of less than 100,000 people, activities in non-contiguous wetlands are not regulated until a wetland inventory is completed. The MDNR can also regulate some activities in wetlands anywhere in the state, regardless of size, if they are determined to be essential to the preservation of natural resources and the landowner has been so notified by the Department.

The Shorelands Protection and Management Act provides for the designation of protected environmental areas along Michigan's Great Lakes shoreline that are important for the preservation and maintenance of fish and wildlife. Environmental areas covered by the Act are usually wetlands or marshes, although some are upland areas or islands. The Act applies to designated property that lies up to 1,000 feet landward of the ordinary high water mark of the Great Lakes or a connecting waterway, and those lands bordering other waters affected by levels of the Great Lakes. The Act does not apply to wetland areas already protected in

Table 4.15 Summary of State Statutes Impacting Wetland Protection and Management in Michigan.

Statute	Description
Goemaere-Anderson Wetland Protection Act, 1979 PA 203	Recognizes wetland values; requires permit for many activities in wetlands.
Inland Lakes & Streams Act, 1972 PA 346	Requires permit for dredging, filling and construction activities in inland lakes and streams and associated wetlands below the ordinary high water mark.
Great Lakes Submerged Lands Act, 1955 PA 247	Requires permit for construction activities in Great Lakes and connecting waters.
Michigan Environmental Protection Act, 1970 PA 127	Prohibits any conduct which is likely to pollute, impair, or destroy a lake, stream or wetland, unless certain public interest conditions are met.
Shorelands Protection and Management Act, 1970 PA 245	Regulates environmental areas (primarily wetlands) along the Great Lakes.
Soil Erosion and Sedimentation Control Act, 1972 PA 347	Requires permit based on soil erosion control plan (issued locally with MDNR oversight) for earth change activities which disturb one or more acre or are within 500 feet of a lake or stream.
Natural Rivers Act, 1970 PA 231	Regulates land use along designated natural rivers through state and local zoning based on corridor management plans.
Subdivision Control Act, 1968 PA 288	Requires approval of the Water Resources Commission for any subdivision plat containing lots in the flood plain, and additional review by MDNR for any subdivision plan involving land abutting a lake or stream.
Administrative Procedures Act, 1969 PA 306	Governs the promulgation of administrative rules for state statutes, and defines the appeal process followed when permit applications under various statutes are denied.
Water Resources Commission Act, 1929 PA 245	Creates a Water Resources Commission to regulate state water resources. The Commission promulgates water quality standards and regulates discharges to state waters and related floodplains. Requires a permit to alter a flood plain.

national parks. Currently, 295 miles of Great Lakes or connecting waters shoreline have been designated as protected environmental areas. This is 9.0 percent of Michigan's 3,288 coastal shoreline miles. Fifty-two miles of protected environmental areas border Lake Superior, 85 are on Lake Michigan, 140 border Lake Huron, 6 are along the Detroit River, and 12 are located on Lake Erie.

Wetland water quality is determined by characteristics and conditions different from those used to evaluate the quality of lakes and streams. In general, natural wetlands are characterized as having very shallow water with abundant vegetation, high organic bottom deposits, and the periodic absence of oxygen throughout the water and bottom sediments (Kadlec 1976). In essence, wetlands are characterized by conditions that are considered undesirable in lakes and streams. Consequently, the quality of wetlands is generally described in terms of their use.

Wetlands are included in Michigan's WQS under the general category "other surface waterbodies within the confines of the state". The antidegradation rule contained in the standards provides some protection to wetlands. However, few of the criteria currently included in the standards are directly applicable to wetlands because of their unique environmental conditions relative to traditional measurements for good water quality.

4.3.7 Hazardous Waste

The generation, treatment, transport, storage and disposal of hazardous wastes are controlled by programs developed under the Hazardous Waste Management Act, 1979 PA 64. Waste disposal sites are also regulated under the federal Resource Conservation and Recovery Act (RCRA), 1976 PL 94-580. Clean ups and other responses to contaminated sites may occur under two programs, the U.S. Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 1980 PL 96-510, commonly referred to as "Superfund", and the Michigan Environmental Response Act (MERA), 1982 PA 307. Both programs utilize risk assessments to evaluate the severity of contamination at specific sites based on known or potential impacts to (mainly) human health and the environment. Sites are then ranked according to their relative severity, thereby establishing priorities for remedial actions. The major difference between the programs is that Superfund sites are assessed based on conditions when the site was at its worst, and site assessments conducted under PA 307 are based on conditions at the time of assessment. Both of these programs may provide funding, on a priority basis, for remedial investigations, feasibility studies and clean up actions prior to identification of, and/or agreement on the course of action with a responsible party.

4.3.8 Pesticides

The use of pesticides is addressed through the Michigan Pesticide Control Act, 1976 PA 171. This act specifies requirements for registration of pesticide products, certification and licensing of pesticide applicators, and investigations of suspected pesticide problems. Public Act 171 adopts major portions of the Federal Insecticide, Fungicide and Rodenticide Act at the state level. This allows the state primacy in the areas of pesticide registration, labelling and distribution; licensure of pesticide dealers; certification of pesticide applicators; and, enforcement. In all other areas, the federal pesticide requirements apply. Pesticide programs are under the jurisdiction of the Michigan Department of Agriculture, which also manages programs for emergency response in cases where contaminants may enter food chains.

4.3.9 Air Quality

The Federal Clean Air Act, as amended in 1970 and 1977, directs the U.S. EPA to establish National Ambient Air Quality Standards. Since 1971, the U.S. EPA has established standards for seven pollutants: suspended particulate matter, sulphur dioxide, nitrogen dioxide, carbon monoxide, ozone (photochemical oxidants), hydrocarbons and lead. Air pollution control is addressed through a permitting process similar to the NPDES process, under the authority of the federal Clean Air Act and the Michigan Air Pollution Act, 1965 PA 348.

The Clean Air Act Amendments were signed into law on November 15, 1990. The Act requires emission standards which reflect maximum achievable control technology to be developed for new and existing major sources of 190 air toxic compounds.

The Act also includes provisions specifically for the protection of the Great Lakes from toxic air pollutants. Michigan served as the lead state on efforts to address Great Lakes protection in the amendments. The Clean Air Act now requires EPA to promulgate emission standards for sources which account for 90% of the emissions of seven designated pollutants (polycyclic organic matter, alkylated lead compounds, hexachlorobenzene, mercury, polychlorinated biphenyls, 2,3,7,8-tetrachlorodibenzofurans and 2,3,7,8-tetrachlorodibenzo-p-dioxin). The Act directs EPA to consider bioaccumulation and food chain effects of air toxics when performing the assessment of residual risks remaining after technology controls are applied.

Additionally, the Act provides for a multi-year study of the extent and effect of atmospheric deposition into the Great Lakes and other waters. A Great Lakes monitoring network must be established by December 31, 1991 which must include a dry and wet deposition monitoring facility on the shores of each of the Great Lakes.

A 14 member Air Toxics Policy Committee was established in December of 1987 by the Michigan Air Pollution Control Commission and the MDNR to develop a long-range strategy for developing rules to regulate, control, and abate the emission of toxic air pollutants from both new and existing sources. The Committee decided to develop rules for new and modified sources first. Atmospheric deposition of toxic pollutants to the Great Lakes was a consideration in the rules development. The Committee presented the proposed regulations for new sources to the Commission in September 1989. Public hearings have been held and a summary of public comments and responses have been completed. Discussions with industry and environmental representatives on further revisions to the draft rules are expected to lead to final agreement on the rules package by the fall of 1991 which will be submitted for the final stages of the legislative process.

Regional initiatives are also currently taking place to facilitate the reduction of toxic air pollutant emissions which can enter the Great Lakes Basin through atmospheric deposition.

The first initiative is the implementation of the Great Lakes States' Air Permitting Agreement. Signed by the Great Lakes Environmental Administrators in November 1988, the agreement commits the air regulatory programs to require the best available control technology for toxics on sources of compounds to the maximum degree allowed under existing authority. Special focus is placed on air emission sources of Great Lakes critical pollutants including mercury, alkylated lead compounds, total polychlorinated biphenyls, hexachlorobenzene, benzo-a-pyrene, 2,3,7,8-tetrachlorodibenzo-p-dioxin and 2,3,7,8-tetrachlorodibenzofurans.

The second major regional initiative is the development of a regional air toxics emission inventory. In order to assure that adequate controls of toxic air pollutants will be required, all sources of toxic air pollutants must be identified. Emission inventories are the mechanism used to ascertain the type of pollutants and quantities emitted by an air pollutant source.

A grant was received from the regional Great Lakes Protection Fund to begin the process for the development of a regional air toxics emission inventory. This fund was established by the eight Great Lakes states to fund research and demonstration projects that focus on the enhancement of Great Lakes ecosystem health. This comprehensive computerized database will identify 25 compounds of potential concern to the Great Lakes Basin emitted from area, point and mobile sources in eight states. If adequate funding is received, the initial computerized database will be completed in approximately 2 years, with the capability of being updated on a regular basis.

The Michigan Urban Air Toxics Monitoring Program was established in January 1990. Sampling is being conducted to obtain information on 29 organic compounds and 13 trace metals surrounding three urban areas. The current sampling locations are in Kalamazoo, Midland and Detroit. Several air toxics monitoring initiatives are also taking place throughout the state of Michigan.

The Air Quality Division (AQD) initiated a background air monitoring project in November 1990. The program is funded, in part, by a grant awarded to the AQD from the Great Lakes Protection Fund. Air monitors are located at three rural areas in Michigan: Sault Ste. Marie, Traverse Bay and Saginaw Bay. Sampling is conducted monthly and will last one year for compounds considered by the International Joint Commission to be "critical pollutants" in the Great Lakes ecosystem. The compounds include: total polychlorinated biphenyls and 90 component congeners, polynuclear aromatic hydrocarbons, hexachlorobenzene, dieldrin and 13 trace metals of concern. The goal of this project is to confirm the presence and magnitude of these pollutants and to develop baseline data for further research projects.

A second research proposal, would incorporate the data obtained from the background study, requested funding from the Great Lakes Protection Fund in summer, 1991. MDNR AQD and the University of Michigan research staff would jointly conduct a study to investigate the transport, deposition and source areas of toxic contaminants measured across Michigan.

If funded, this project will collect ambient samples of the same compounds at three sites in Saginaw Bay, South Haven and Traverse City, followed by analysis using hybrid receptor modelling to evaluate atmospheric transport and source regions.

4.3.10 Fish Consumption Advisories

The Michigan Department of Public Health (MDPH) has issued fish consumption advisories since the early 1970s in an effort to provide guidance to the public on ways to reduce their exposure to contaminants from fish. The advisories are intended primarily for the frequent fish consumer because body burdens and risk of health problems from contaminants increase over time with repeated exposure. Because the impacts on reproduction and child development are largely unknown, pregnant women, nursing mothers, women who anticipate having children and children age 15 and under are especially advised not to consume contaminated fish.

The MDPH has adopted contaminant concentrations for edible portions of fish which, when exceeded, trigger consideration of a fish consumption advisory (Table 4.16). These "trigger levels" are based on U.S. Food and Drug Administration (FDA) regulatory guidelines, and the application of risk assessments.

Three different types of advisories may be issued depending on the percentage of specimens from a sample that exceed the trigger level(s). Advice on fish consumption for organic compounds is based on the following criteria:

a) No advisory for limiting consumption will be issued when contaminants are undetected or when 10 percent or less of the tests for a particular fish species and location exceed any of the advisory trigger levels as shown in Table 4.16.

b) An advisory for reduced consumption to <u>no more than one meal per week</u> will be issued when any of the advisory trigger levels are exceeded by more than 10 percent but less than 50 percent of the specimens tested for a particular species and location, and the mean concentrations do not exceed the trigger levels for the contaminants found. Nursing mothers, pregnant women, women who anticipate bearing children and children age 15 and under would be advised not to eat these fish. Michigan is likely to change this advisory to "Nursing mothers ..., and children <u>under age 15</u> ..." in the 1991 advisory to promote consistency among the Great Lakes jurisdictions.

c) A "<u>No Consumption</u>" advisory will be issued when any advisory trigger level is exceeded by 50 percent or more of the specimens tested of a particular species and location.

Table 4.16 Trigger Levels Currently Used by MDPH in Establishment of Fish Consumption Advisories.

Chemical	MDPH Advisory Trigger
Chlordane	0.3 ppm
DDT	5.0 ppm
DDT metabolites (DDE, DDD)	5.0 ppm
Dieldrin (aldrin)	0.3 ppm
Dioxin (2,3,7,8 TCDD)	10.0 ppt*
Endrin	0.3 ppm
Heptachlor	0.3 ppm
Mercury	0.5 ppm*
Mirex	0.1 ppm
PCB	2.0 ppm
Toxaphene	5.0 ppm

*Different than FDA Regulatory or Advisory Guidelines; FDA uses 25 ppt for dioxin and 1.0 ppm for mercury; all others are currently the same.

Advice on fish consumption for mercury is based on a regression analysis of fish length versus mercury concentration. Consumption advisories due to mercury contamination would be issued for particular size categories as follows:

a) No advisory for limiting consumption will be issued when concentrations of mercury for a particular fish species and location are less than 0.5 ppm.

b) An advisory for reduced consumption to no more than one meal per week will be issued when mercury concentrations in a particular species from one location are between 0.5 and 1.5 ppm. Nursing mothers, pregnant women, women who intend to have children, and children age 15 and under should eat no more than one meal per month of the identified fish.

c) A "No Consumption" advisory will be issued when the mean mercury concentration in a particular species from one location exceeds 1.5 ppm.

When sufficient information to fully characterize the degree of contamination or human health risk does not exist, a precautionary position will be advocated until the situation can be fully evaluated.

The Health Advisory on fish consumption is published annually as part of the Michigan Fishing Guide. The advisory for the St. Marys River AoC is discussed in Chapter 6. The fishing guide is provided to each individual who purchases a fishing license, and is available free of charge from MDNR, MDPH and local health departments. Notices of consumption advisories are provided to the press and editors of sports journals.

4.3.11 Drinking Water Standards

The responsibility for drinking water regulations at the federal level is with the U.S. EPA. The federal Safe Drinking Water Act (SDWA) as amended in 1986 (PL 99-339, 100 State. 642) requires U.S. EPA to publish "maximum contaminant level goals" (MCLGs) for contaminants which in the judgement of the Administrator may have any adverse human health effects and which are known or anticipated to occur in public water systems. In addition to publishing a MCLGs, which are non-enforceable health goals, the U.S. EPA must promulgate National Primary Drinking Water Regulations (NPDWR). The NPDWR may include either (a) a maximum contaminant level (MCL) or (b) a treatment technique. A treatment technique may be set only if it is not economically or technologically feasible to ascertain the level of a contaminant. An MCL must be set as close to the MCLG as feasible.

The 1986 amendments to the SDWA require the U.S. EPA to promulgate NPDWRs for 83 contaminants in three phases, by June 19, 1989. EPA has not met this schedule. In December of 1975, EPA published National Interim Primary Drinking Water Regulations for ten inorganic chemicals, six pesticides, and two microbiological indicator contaminants (total coliforms and turbidity). Some of these Interim Regulations, such as fluoride and coliform, have been finalized as NPDWRs. Other parameters such as Giardia and viruses, are being addressed by U.S. EPA through the establishment of required treatment techniques. The U.S. EPA is continuing to develop and promulgate NPDWRs for the remaining 83 contaminants.

National Primary Drinking Water Regulations under the SDWA are also to include monitoring requirements which assure a drinking water supply will dependably comply with the MCLs. The SDWA also contains public notification requirements should a public water supply (1) fail to comply with the MCL or treatment technique; (2) fail to comply with any monitoring requirements; (3) obtain a variance or exemption; or (4) fail to comply with any requirements of any schedule prescribed pursuant to a variance or exemption.

The federal SDWA delegates authority for the implementation of the Act to the states where the state has legislation which equals or exceeds the requirements of the Act. Any modifications to or deviations from the requirements must be approved by U.S. EPA.

The MDPH has had a drinking water program since 1913. The Michigan Safe Drinking Water Act, 1976 PA 399, was passed in 1976 with rules becoming effective in 1978. The Michigan SDWA authorizes the MDPH to provide for the supervision and control of public water supplies. The State regulations adopt the federal MCLs for organic and inorganic chemicals, microbiological contaminants, and turbidity contained in the federal act, except for radioactivity. There is no MCL for corrosivity, however monitoring requirements exist, and the water must be noncorrosive. The Michigan standards have been approved by the U.S. EPA as equivalent to or more stringent than the federal MCLs. A complete list of the MCLs and monitoring requirements for community water systems in Michigan is given in Appendix 4.5.

Drinking water standards apply after treatment either at the point of entry into the distribution system (plant tap), or at the point of use (the customer's tap) depending on the contaminant. The required sampling location for each contaminant is identified in Appendix 4.5. Drinking water standards do not apply to the raw water as taken from the waterbody (i.e. before treatment).

Michigan's Act 399 also requires that a complete treatment system be provided for all public water supplies using a surface water source. Act 399 defines a complete treatment system as a "treatment system employing disinfection, coagulation, sedimentation, and filtration units which function collectively to effect control over water quality characteristics to produce a finished water meeting the State drinking water standards".

4.3.12 Michigan Waste Prevention Strategy

In February 1991, MDNR completed the development of a comprehensive strategy to reduce, at the source, waste generated by individuals, businesses and state government. The concept of waste prevention is relatively simple: If a waste is not created in the first place, it can never cause damage later. By avoiding the generation of waste at the source, waste prevention strategies are inherently the most protective of human health and the environment.

While it is true that progress has been made over the past several decades through expanded use of pollution controls and waste management practices, many persistent environmental problem remain. Environmental problems have become more difficult to predict and avoid when relying on pollution control alone. In short, such practices can no longer be relied on as the primary strategy to protect the environment, human health and, ultimately economic sustainability.

Michigan's Waste Prevention Strategy provides a vision in which future discharges to the air, water and land would be allowed only after a determination is made that there is no prudent and feasible alternative to its creation and discharge; and even then, only after sufficient treatment has been applied to meet the best available treatment technology requirements and other applicable standards. To realize this vision will mean a fundamental shift in permitting programs, which requires changes in statutes and rules.

A number of actions and recommendations to speed the implementation of waste prevention by individuals, businesses and state government are set forth in the strategy document. Recommendations include: enhanced education and promotion efforts for waste prevention; training programs; on-site technical assistance provisions to businesses; convening groups to discuss the feasibility of waste prevention initiatives in compliance and enforcement orders, environmental permits, cross-media inspections, banning certain toxic chemicals, etc.; and developing and implementing waste prevention plans for all state departments.

An implementation plan for the strategy is currently under development and will identify priority recommendations, funding sources, responsible parties and timelines. Waste prevention initiatives, particularly as they relate to the regulated community, will be stressed in the consideration of the conduct of various demonstration projects and in the consideration of remedial action options to address use impairments in the Stage II RAPs.

4.4 UNITED STATES - CANADA GREAT LAKES WATER QUALITY AGREEMENT

The Great Lakes Water Quality Agreement (GLWQA) was first signed by the governments of the United States and Canada in 1972 as a result of concern about degraded water quality in the Great Lakes. The Agreement confirmed both governments' commitment to enhance and restore Great Lakes water quality. The 1972 GLWQA provided the focus for a coordinated effort to control phosphorus inputs to the lakes, thereby addressing the eutrophication problem. In 1978, the GLWQA was revised and expanded in recognition of the need to understand the effects of toxic substances and control their discharge to the Great Lakes. The concept of an ecosystem approach to Great Lakes water quality management was also incorporated into the 1978 GLWQA. A protocol amending the GLWQA was signed by the two governments in 1987. The protocol adds specific programs, activities and timetables to address the issues identified in the 1978 Agreement.

The Agreement adopts General and Specific Objectives for the Great Lakes system, and sets forth the basic requirements for RAPs and Lakewide Management Plans (LMPs). Annexes of the GLWQA address specific issues such as the control of phosphorus, discharges of polluting substances and wastes from vessels, dredging, surveillance and monitoring, point and nonpoint sources, etc. The GLWQA objectives, and the Annexes are described in the following sections.

4.4.1 General Objectives

The General Objectives of the GLWQA are found in Article III. General Objectives are broad descriptions of desired water quality conditions consistent with the protection of beneficial uses. These conditions include the absence of sludge deposits, floating materials, materials and heat producing color, odour, taste impairment or toxicity, and excessive nutrients. The General Objectives are intended to provide overall water management guidance to achieve a level of environmental quality to which both governments have agreed.

4.4.2 Specific Objectives

The specific objectives are described in Article IV of the GLWQA and listed in Annex 1. The objectives represent minimum levels of water quality and maximum concentrations of toxic substances in fish tissue agreed to by both federal governments. Under the agreement, the objectives may be amended, or new objectives added by mutual consent of both governments.

The 1987 amendments to the Agreement clarify that the Specific Objectives are consistent with the other portions of the Agreement (e.g. to virtually eliminate the discharge of any or all persistent toxic substances). Therefore, the Specific Objectives identified in Annex 1 for persistent toxic substances are adopted as Interim Objectives. A persistent toxic substance is defined as any toxic substance with a half-life in water of greater than eight weeks. A summary of the Specific Water Quality Objectives from Annex 1 is provided in Table 4.17. The reader is referred to the GLWQA for a complete listing.

Table 4.17 Great Lakes Water Quality Agreement Specific Objectives for Ambient Water Quality. (All concentrations are in µg/L unless otherwise noted.)

Parameter	Specific Objectives (µg/L)
Inorganics*	
Arsenic	50.0
Cadmium	0.2
Chromium	50.0
Copper	5.0
Iron	300.0
Lead	†
Mercury	0.2
Nickel	25.0
Selenium	10
Zinc	30.0
Fluoride	1200.0
Total Dissolved Solids (mg/L)	200‡
Ammonia, unionized	20.0
Total	500.0
Organics	
Aldrin + Dieldrin	0.001
Chlordane	0.06
DDT + metabolites	0.003
Endrin	0.002
Heptachlor + Heptachlor Epoxide	0.001
Lindane	0.01
Methoxychlor	0.04
Mirex	§
Toxaphene	0.008
Dibutyl phthalate	4.0
Di(2-ethylhexyl)phthalate	0.6
Other phthalic acid esters	0.2
Phenol	1.0
Diazinon	0.08
Guthion	0.005
Parathion	0.008
Unspecified, persistent organic compound	§

* All metals (except mercury) are the total of all forms present in an unfiltered sample. Total mercury shall be measured in a filtered sample.

† Value for Lake Superior - 10 µg/L; Lake Huron - 20 µg/L; remaining Great Lakes - 25 µg/L.

‡ Present (as of 1978) levels should be maintained, but 200 mg/L must not be exceeded.

§ Should be less than detection levels as determined by the best scientific methodology available.

Specific objectives for contaminant concentrations in fish for the protection of human health, and fish eating birds are shown in Table 4.18.

Table 4.18 GLWQA Specific Objectives for Fish Tissue.
(Concentrations are given in $\mu g/g$ on a wet weight basis.)

Parameter	Concentration in Edible Portion*	Whole Fish†
Mercury	---	0.5
PCB	---	0.1
Aldrin + Dieldrin	0.3	---
DDT + metabolites	---	1.0
Endrin	0.3	---
Heptachlor + Heptachlor epoxide	0.3	---
Lindane	0.3	---
Mirex	---	‡

Note: "---" indicates that the GLWQA does not contain specific objectives.
* Great Lakes Water Quality Agreement objectives for protection of human consumers of fish.
† GLWQA specific objectives for protection of birds and animals which consume fish.
‡ Concentrations should be less than detection as determined by the best scientific methodology available.

4.4.3 GLWQA Annexes

There are 17 annexes to the GLWQA. They are an integral part of the Agreement and set forth objectives, principles, programs, and reporting requirements to which both federal governments have agreed. As such, the annexes must also be considered in the development of the RAP.

Annex 1, previously described, lists the Specific Objectives and requires the compilation of three lists of substances which are present or potentially present within the water, sediment or aquatic biota of the Great Lakes System and believed to have acute or chronic toxic effects on aquatic, animal or human life. The first list identifies known toxicants present in the aquatic ecosystem. The second list identifies compounds which are present and suspected of causing toxic effects on aquatic, animal or human life. The third list is used to identify known toxicants which may be present in the aquatic ecosystem. To date, the Parties have made little progress toward compilation of these lists.

Annex 2 discusses the Remedial Action Plans (RAPs) and Lakewide Management Plans (LMPs), including the designation of Areas of Concern (AoCs), and the contents and reporting requirements for RAPs and LMPs. While most of the jurisdictions have actively worked toward development of RAPs for the AoCs, the Parties have made little progress in development of LMPs for the Great Lakes.

Annex 3 includes programs for the control of point and non-point sources of phosphorus into the Great Lakes System. For example, in 1976, the estimated total phosphorus load to Lake Erie was 20,000 metric tons per year. The estimated load that will be discharged when all municipal waste treatment facilities over 1 MGD achieve compliance with the 1 mg/L effluent concentration (as required by Article VI of the GLWQA) will be 13,000 metric tons per year to Lake Erie. The phosphorus target load (point and non-point sources combined) for Lake Erie is 11,000 metric tons/year to meet ecosystem objectives.

Annexes 4, 5, 6, 8, and 9 address the discharge of oil and hazardous polluting substances and wastes from vessels and onshore and offshore facilities. These annexes set forth criteria to be adopted by both countries for (1) the prevention of discharges of oil and hazardous polluting substances; (2) the prohibition of discharge of garbage; (3) the prohibition of discharge of wastewater (including ballast water) in harmful amounts or concentrations; and (4) the requirement for vessels to contain, incinerate, or treat sewage to an adequate degree.

Efforts to prevent introductions of zebra mussels by way of ballast water were undertaken by the U.S. and Canadian Coast Guards, acting under the GLWQA. The Canadian Coast Guard in consultation with the U.S. Coast Guard, St. Lawrence Seaway Authority, Shipping Association, Fisheries and Oceans Canada, Environment Canada and the Great Lakes Fisheries Commission, established voluntary guidelines that became effective May 1, 1989. These guidelines specify that ships entering the Seaway should exchange their ballast off the continental shelf at depths greater than 2000 meters. In the event that this is not possible, ballast water may be exchanged in the Laurentian Channel in the Gulf of St. Lawrence.

The Canadian Coast Guard and U.S. Coast Guard are responsible for the review of services, systems, programs, recommendations, standards and regulations relating to shipping activities for the purpose of maintaining or improving Great Lakes water quality. Annex 9 provides for the continued maintenance of the joint contingency plan (CANUSLAK) developed under Annex One of the Canada - United States Joint Marine Contingency Plan. The purpose of the plan is to provide for a coordinated and integrated response to pollution incidents in the Great Lakes System.

Annex 7 establishes a subcommittee under the IJC Water Quality Board to review dredging practices and to develop guidelines and criteria for dredging activities in the boundary waters of the Great Lakes Systems. The subcommittee is also responsible for development of specific criteria to classify contaminated sediments of designated areas of intensive and continuing dredging activities in the Great Lakes System.

Annex 10 directs the Parties to establish and maintain two lists of substances known to have, or potentially have, toxic effects on aquatic or animal life of which there is a risk of being discharged into the Great Lakes System. These lists are included as Appendices 1 and 2 of the Annex. The two governments are directed to develop and implement programs to minimize or eliminate the risk of release of these substances into the Great Lakes System.

Surveillance and monitoring activities are outlined in Annex 11. In general, the purpose of these activities is: (1) to ensure that jurisdictional control requirements are being met, (2) to gather data to measure the progress toward achieving the General and Specific Objectives, (3) to evaluate water quality trends, and (4) to identify emerging water quality problems. This annex supports the development of RAPs and LMPs pursuant to Annex 2.

Annex 12 defines persistent toxic substances and sets forth regulatory strategies and programs to be adopted by both countries for controlling or preventing the input of such substances into the Great Lakes Systems. Monitoring and research programs, including the establishment of an early warning system to anticipate future toxic substances problems and the establishment of action levels to protect human health, are addressed in this annex. The general principles to be followed in the development and adoption of regulatory strategies and programs under this Annex include the virtual elimination of the input of persistent toxic substances, and the reduction in generation of contaminants.

Annex 13 further delineates programs and measures for the abatement and reduction of nonpoint sources of pollution from land-use activities. These measures include efforts necessary to further reduce nonpoint source inputs of phosphorus, sediments, toxic substances and microbiological contaminants contained in drainage from urban and rural land, including waste disposal sites, in the Great Lakes Systems. The annex refers to RAPs and LMPs as information sources to identify nonpoint source concerns, and to assist in the development and implementation of watershed management plans. The annex also calls for the identification and preservation of wetland areas and the determination of nonpoint source pollutant loadings to the Great Lakes System.

Annex 14 is an agreement between the two countries to study the issue of contaminated sediments, determine the impact of contaminated sediment on the Great Lakes Basin Ecosystem, and develop a standard approach and agreed procedures for the management of contaminated sediment. The annex requires the governments of both countries to evaluate existing technologies for the management of contaminated sediment and to implement demonstration projects at selected AoCs. Information obtained through this research should be used to guide the development of RAPs and LMPs.

Atmospheric deposition of toxic substances to the Great Lakes Ecosystem is addressed in Annex 15. The annex requires that the Parties conduct research to determine pathways, fate and effects of airborne toxic substances in the Great Lakes Systems. An Integrated Atmospheric Deposition Network is to be established to (1) identify and track airborne toxic substances; (2) determine atmospheric loadings of toxic substances to the Great Lakes System; and (3) define temporal and spacial trends in the atmospheric deposition of toxic substances. Pollution control measures will be developed and implemented for sources found to have significant adverse impacts on the Great Lakes System.

Annex 16 directs the governments of both countries to identify and assess the impact of contaminated groundwater on the Great Lakes System. This information should be used in the development of RAPs and LMPs. The governments agree to control the sources and the contaminated groundwater itself.

Annex 17 describes research necessary to achieve the goals of the GLWQA. This includes research of the sources and fate of toxic substances in the Great Lakes System, and their ecotoxicity. Also addressed are research needs on the effects of varying the lake levels, and the impact of water quality and the introduction of non-native species on fish and wildlife populations and habitats. The need for the development of control technologies for point source discharges, for action levels for contamination which incorporate multimedia exposure, and for epidemiological studies to determine the long-term, low-level effects of toxic substances on human health are also discussed in this annex.

4.5 ONTARIO-MICHIGAN EMERGENCY NOTIFICATION PROTOCOL

The Province of Ontario and the State of Michigan have agreed to notify each other and provide appropriate information in the event of an accidental discharge to the water or air in areas that may have transborder impacts. Detailed emergency notification procedures outlining contact responsibilities and orders have been established for spills originating in both Ontario and Michigan. Notification flow diagrams are provided in Figures 4.1 and 4.2, respectively.

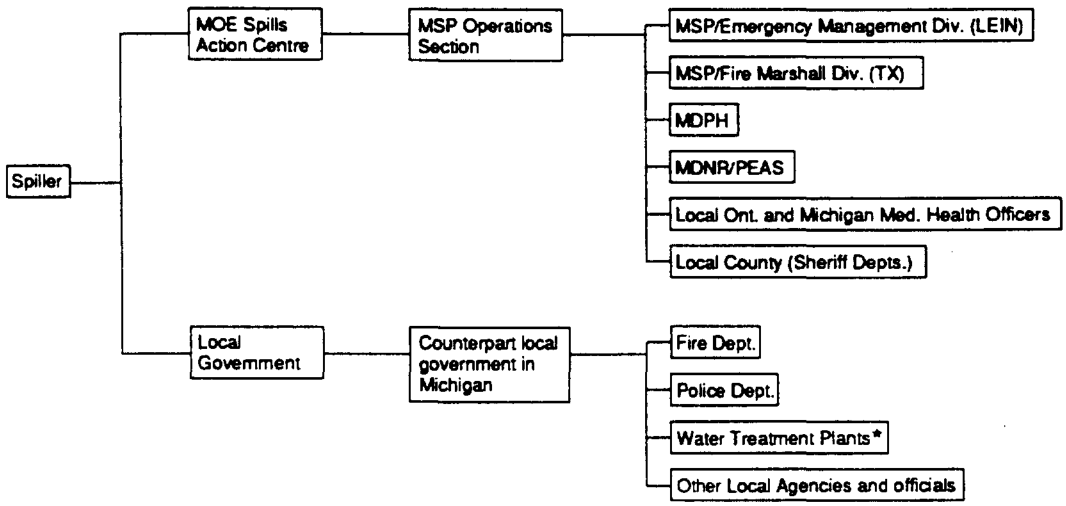
In the event of a spill in the transborder area of Ontario the spiller will contact the local government in Ontario and the OMOE-Spills Action Centre. The local government contacts their Michigan counterpart while the OMOE Spills Action Centre will contact the Michigan State Police (MSP) Operations Section. The local governments in Michigan will contact the Fire Department, Police Department, water treatment plants and other local agencies. The MSP Operations Section will contact MSP/Emergency Management Division, MSP/Fire Marshall Division, Michigan Department of Public Health, local Ontario and Michigan Medical Officers of Health, MDNR/Pollution Emergency Alert System and the local county sheriff departments.

In the event of a spill in the transborder area of Michigan the spiller will contact the local government who will contact the MSP/Operation Section and their Ontario counterpart. The MSP Operations Section will contact the MSP/Emergency Management Division, MSP/Fire Marshall Division, Michigan Department of Public Health, local Ontario and Michigan Medical Officers of Health, MDNR/Pollution Emergency Alert System and OMOE Spills Action Centre.

Figure 4.1

St. Marys River Remedial Action Plan

Notification flow diagram for spills originating in Ontario

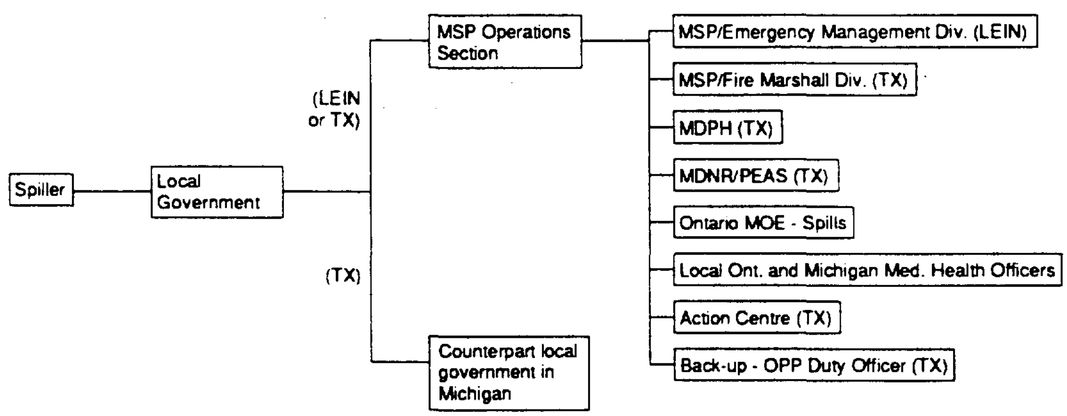


* notified of all events

Figure 4.2

St. Marys River Remedial Action Plan

Notification flow diagram for spills originating in Michigan



5 ENVIRONMENTAL SETTING

5.1 LOCATION, EXTENT AND HYDROLOGY

5.1.1 Location and Extent

The St. Marys River is the outlet from Lake Superior and leaves the lake from Whitefish Bay flowing in a generally southeasterly direction through several channels to Lake Huron, a distance of from 100 to 120 km, depending upon the route taken (Figure 5.1). The river drops approximately 6.7 m, with most of this drop (6.1 m) occurring at the St. Marys Rapids. There are several islands in the St. Marys River the largest of which Sugar, St. Joseph, Neebish and Drummond, are inhabited year-round.

The Area of Concern (AoC) for the St. Marys River being addressed by the Remedial Action Plan (RAP) extends from Whitefish Bay at an imaginary line drawn between Point Iroquois (Michigan) and Gros Cap (Ontario) to lines from Quebec Bay (Ontario) and Humbug Point (Ontario) on the St. Joseph Channel, and Point Aux Frenes (Michigan) and Hay Point (Ontario) on the West Neebish Channel (Figure 5.1).

5.1.2 Drainage Basin

The St. Marys River has a very large drainage basin because it drains all of Lake Superior and its watershed. Drainage from the Great Lakes is from Lake Superior through Lakes Huron, Erie and Ontario before finally discharging into the St. Lawrence River (Table 5.1).

The St. Marys River immediate watershed is comprised of a number of small to medium-sized watersheds that drain directly into the St. Marys River (Figure 5.2). Collectively, these watersheds include some 2,600 km^2 of land and 230 km^2 of water. On the Michigan side, these include the Waiska River, several small streams in the vicinity of Sault Ste. Marie and north of the Charlotte River, the Charlotte River, Little Munuscong River, Munuscong River and the Gogomain River. On the Ontario side, the watersheds include the Big and Little Carp Rivers, Bennett Creek, East and West Davignon Creeks, Root River, Garden River, Echo River and Bar River.

Table 5.1 Summary of physical characteristics of the Great Lakes connecting channels (Duffy *et al.*, 1987, Botts and Krushelnicki, 1987).

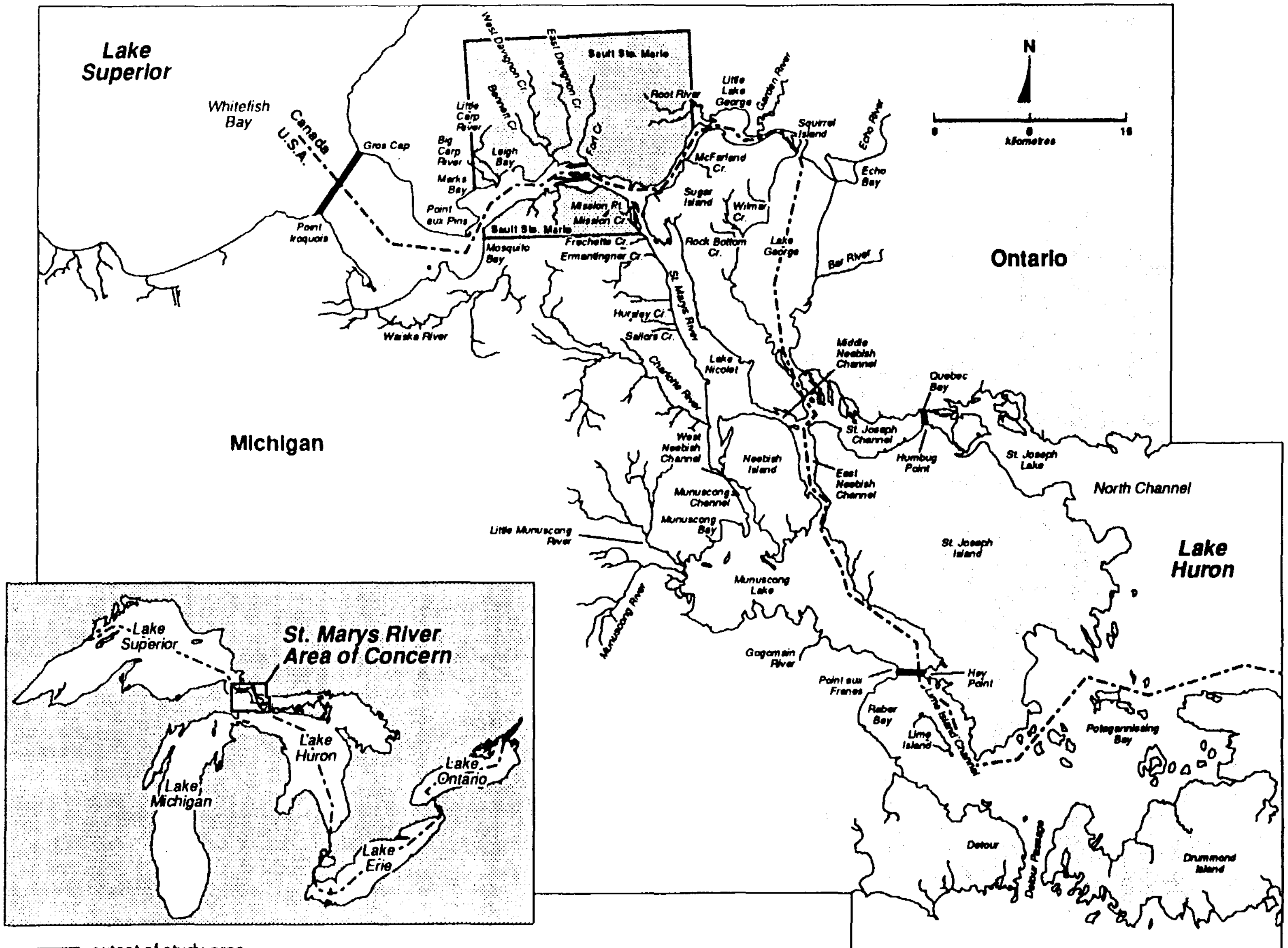
Connecting Channel	Length (km)	Net Elevation Change (m)	Average Flow (m^3/sec)	Watershed area (x 10^3 km^2)		
				Land	Water	Total
St. Marys River	112	6.7	2,100	127.7	82.1	209.8
St. Clair River	43	1.5	5,300	379.8	199.5	579.3
Detroit River	51	1.0	5,400	397.5	200.7	598.2
Niagara River	59	99.3	5,700	457.8	225.2	683.0
St. Lawrence River	808	74.0	6,700	521.8	244.2	766.0

Figure 5.1

St. Marys River Remedial Action Plan

Location map of the St. Marys River Area of Concern

(after UGLCCS 1988)



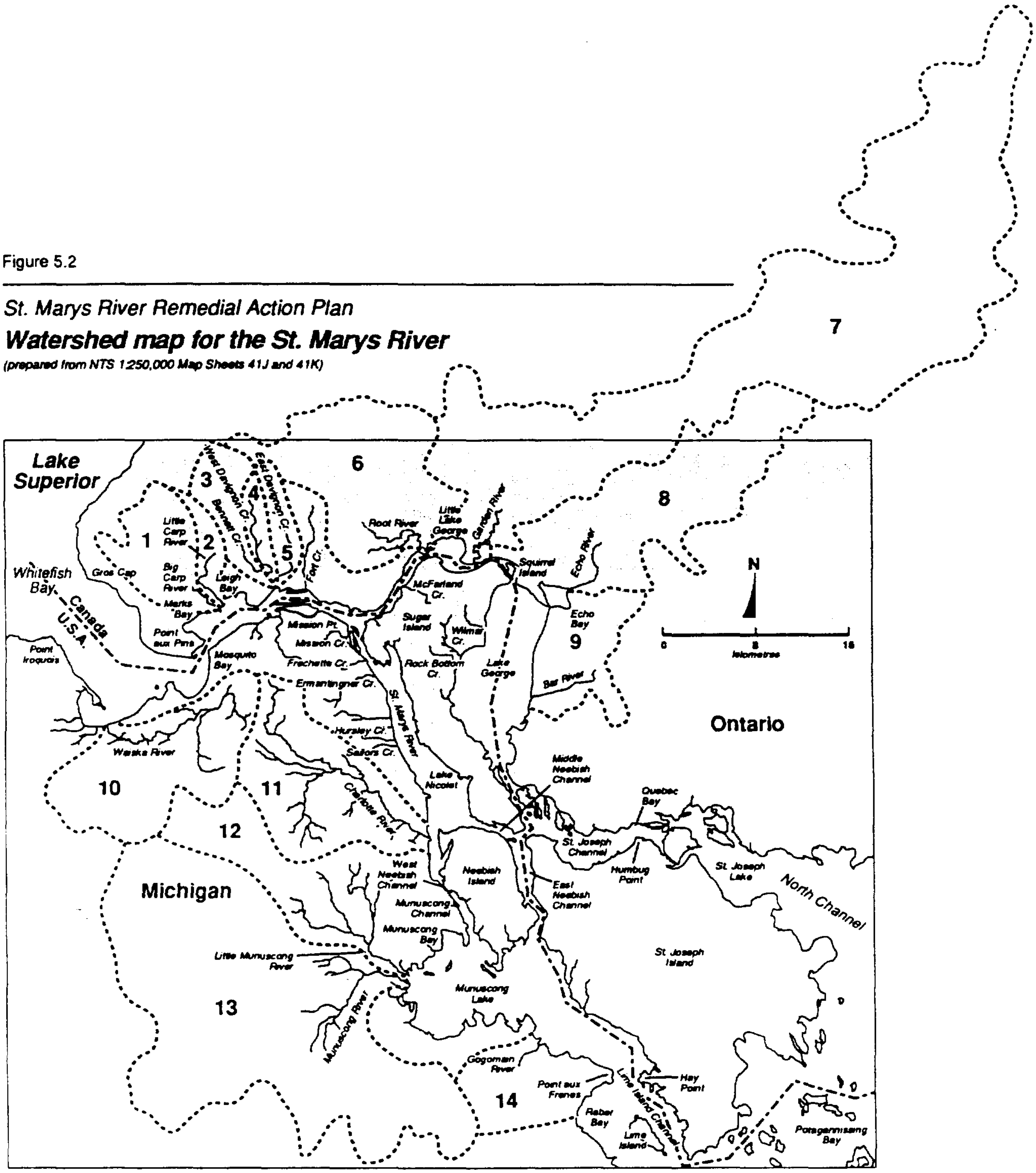
extent of study area

Figure 5.2

St. Marys River Remedial Action Plan

Watershed map for the St. Marys River

(prepared from NTS 1:250,000 Map Sheets 41J and 41K)



---------- watershed boundary

Canada		U.S.
1 Big Carp River	**6** Root River	**10** Waiska River
2 Little Carp River	**7** Garden River	**11** Charlotte River
3 Bennett Creek	**8** Echo River	**12** Little Munuscong River
4 West Davignon Cr.	**9** Bar River	**13** Munuscong River
5 East Davignon Cr.		**14** Gogomain River

Table 5.2 shows the estimated annual discharge and flow rate for the Michigan tributaries discharging to the St. Marys River. In Ontario, the Root River is the only tributary that is regularly monitored. Its mean instantaneous discharge from 1971 through 1988 is 2.00 m^3/s. Additional tributary flow information is collected by the Department of Fisheries and Oceans Sea Lamprey Control programs during the chemical treatment of streams. Average flow rates, measured at the mouth of each stream during May and/or June from 1959 through 1990, for 17 Ontario streams are shown in Table 5.3.

Lake Superior exerts the most influence on the water budget of the St. Marys River. The flow information in Tables 5.2 and 5.3, when compared with the average flow rate for the St. Marys River in Table 5.1, shows that the cumulative flow from tributaries on both sides of the river contributes approximately 1% to the total flow of the St. Marys River.

5.1.3 Hydrology

5.1.3.1 Physical Setting

There are three reaches within the St. Marys River described as follows:

1. The upper river between Whitefish Bay and the St. Marys Rapids: 2.5 km long, decreasing in width rapidly, and characterized by sandy gravel, rubble or rocky shoals with emergent wetlands in protected areas.

2.5
1.2
3.7

2. The St. Marys Rapids: 1.2 km long and 1.6 km wide with a drop of 6.1 m. The river bed is comprised of boulders larger than 1.0 m in diameter and exposed bedrock with localized patches of sand and gravel.

97.3

3. The lower river from the St. Marys Rapids to the narrows at De Tour: includes four large islands of which Sugar, Neebish and Drummond belong to Michigan, and St. Joseph to Ontario. There are also more than 100 smaller islands <4 km^2 in area. Sugar Island splits the river into Lake George on the east and Lake Nicolet on the west (Figure 5.1). Approximately ~~75%~~ 74 of the river's flow courses through Lake Nicolet, while the remaining 26% flows through Lake George (Duffy *et al.*, 1987). Both lakes empty into two channels formed by St. Joseph and Neebish Islands and the Michigan mainland. Waters from Lake George also flow into a third channel formed by the Ontario shoreline and St. Joseph Island (Figure 5.1). Below Neebish Island, the first two channels discharge into Munuscong Bay, where the river widens and flows southeasterly before discharging into Lake Huron between Drummond Island and Michigan. The third channel flows easterly and widens into the North Channel portion of Lake Huron. The lower river is bordered on the west by extensive areas of emergent wetlands which merge into forested or palustrine wetlands. The lower river's east border has higher relief and palustrine wetlands are generally restricted to tributary mouths. The eastern shore is comprised of unconsolidated or rocky shores in exposed reaches, with emergent wetlands occupying the more protected areas (Duffy *et al.*, 1987).

Table 5.2 Average annual flow rates and drainage area for Michigan tributaries discharging to the Marys River (MDNR, Data Files).

Stream	Drainage Area (km^2)	Annual Average Discharge (m^3/s)
Waiska River	396.3	4.5
Ashmum Creek	10.9	0.12
Charlotte River	132.1	1.5
Little Munuscong River	111.4	1.3
Munuscong River	NA	NA
Gogomain River	95.8	1.1
Mission Creek	7.8	0.09
Frechette Creek	6.0	0.07
Ermatinger Creek	14.5	0.17
Hursley Creek	5.7	0.06
Sailors Creek	6.7	0.08
Total		8.99

NA - Data not available

Table 5.3 Average flow rates during May and or June, 1959 to 1990, for Ontario tributaries discharging to the St. Marys River (DFO/USFWS, Sea Lamprey Control Office, Data Files).

Stream	Number of Treatments (Number of Samples)	Flow (m^3/s)	
		Range	Average
East Davignon*	3	0.45 - 0.17	0.32
West Davignon*	9	0.19 - 0.71	0.38
Little Carp*	7	0.17 - 0.99	0.44
Big Carp*	8	0.23 - 2.04	0.63
Root†	8	1.02 - 5.21	2.23
Garden†	9	4.25 - 17.89	8.86
Echo†	11	0.57 - 3.31	1.59
Bar†	1		0.20
Sucker‡	9	0.30 - 0.45	0.19
Two Tree‡	5	0.08 - 0.85	0.45
Richardson‡	5	0.11 - 0.46	0.31
Watson‡	7	0.06 - 0.25	0.12
Gordon‡	7	0.01 - 0.20	0.10
Brown‡	8	0.03 - 0.40	0.17
Koshkawong‡	7	0.20 - 1.22	0.58
H-65 Unnamed‡	2	0.03 - 0.06	0.05
H-68 Unnamed‡	3	0.06 - 0.11	0.08
Total 17 streams		0.01 - 17.89	16.70

*Upstream of the Compensating Gates
†Downstream of the Compensating Gates, excluding island streams
‡Located on St. Joseph Island

5.1.3.2 History of Engineering Structures Influencing Hydrology of the St. Marys River

Over the years, the St. Marys Rapids and river have been extensively modified in order to improve navigation between Lake Superior and Lake Huron. The construction of locks, navigation channels and dredging have increased shipping activity. Subsequently hydropower, railway and highway traffic have also increased. The effect of these activities has heightened concerns regarding possible impacts on aquatic biota and their environment (Duffy *et al.*, 1987, Grimm 1989).

A chronology of engineering events at the St. Marys Rapids is summarized in Table 5.4. There are navigation locks on both sides of the river, two canals and four locks on the Michigan side and one canal and lock on the Ontario side (Figure 5.3). Because of a wall collapse, the Ontario lock has been closed since 1988. Three hydroelectric generating facilities, two in Michigan and one in Ontario, are located at the Rapids (Figure 5.3). Compensating works, a series of 16 gates, were constructed at the head of the rapids (Figure 5.3) in 1921 in order to control the flow over the rapids and divert water to the power and navigation canals. Monthly discharge rates through the compensating gates are currently set by the IJC (Appendix 5.1).

Table 5.4 Chronology of engineering changes associated with the St. Marys Rapids, 1797 to 1986 (Duffy *et al.*, 1987, Kauss 1991).

Year	Event
1797	Navigation lock 11.5 m long constructed on Canadian Side.
1822	Raceway and sawmill built on American side by U.S. Army.
1839	Navigation canal started on American side, construction later aborted.
1855	Navigation lock completed on American side; construction begun in 1853.
1859	Dredging of lower Lake George Channel completed.
1881	Weitzel Lock on American side completed.
1888	International railway bridge completed.
1894	Dredging of Lake Nicolet Channel completed.
1896	Canadian government canal and lock completed. Old state locks on American side replaced by Poe Lock.
1901	Construction of compensating works begun.
1902	Sault Edison Hydroelectric Canal and power plant completed; canal diverted enough water to operate 41 turbines, each using approximately 10.6 m^3/s (total capacity: 435 m^3/s).
1908	Ship canal through West Neebish Rapids (rock cut) completed.
1914	Davis Lock on American side completed.
1915	Additional 37 turbines added to Sault Edison hydroelectric plant.
1916	Hydroelectric canal and plant completed on Canadian side.
1919	Sabin Lock on American side completed.
1921	Construction of 16-gate compensating works completed and monthly river discharges are set by the IJC.
1927	Widening of Middle Neebish Channel completed.
1933	Widening of canal through West Neebish Rapids completed.
1943	MacArthur Lock on American side completed, replacing Weitzel Lock.
1969	Abitibi Paper Company water use reduced from approximately 198 to 1 m^3/s permanently.
1982	Great Lakes Power hydroelectric power plant (now the Clerque Generating Station) on Canadian side redeveloped and capacity increased from 510 to 1,076 m^3/s.
1985	Berm constructed to maintain water level over rapids along Canadian shore. (St. Marys Rapids-Whitefish Island Remedial Works for Fishery).

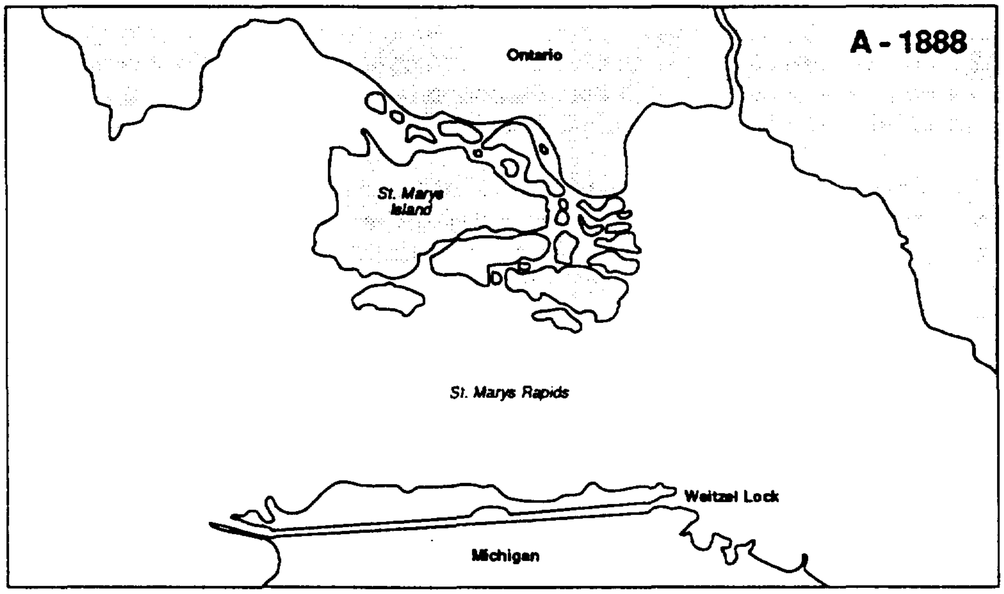
Figure 5.3

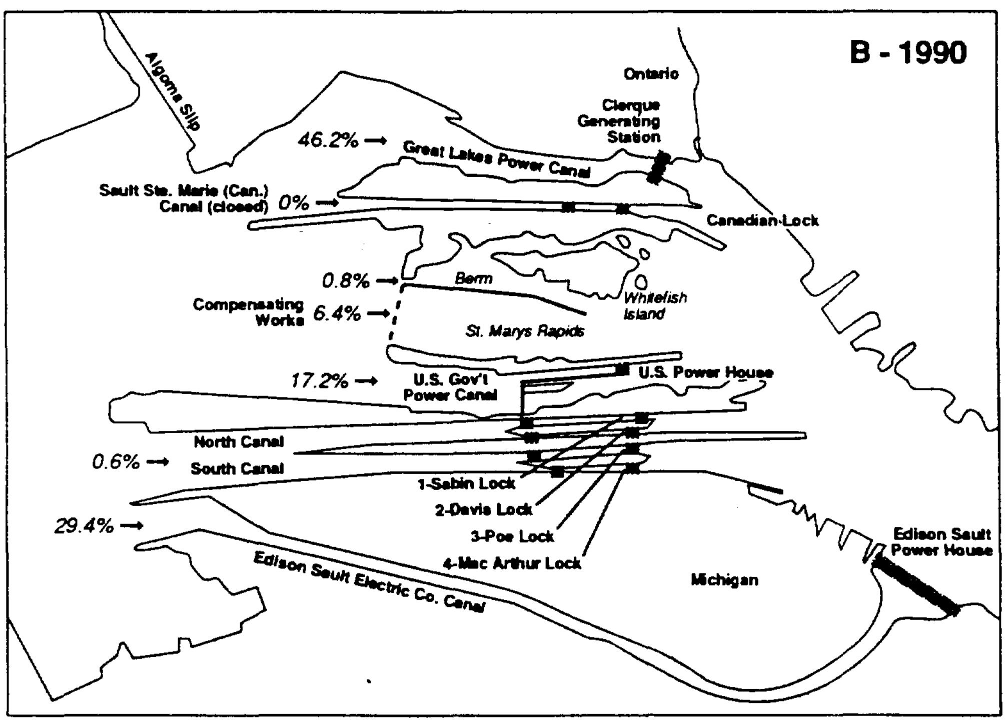
St. Marys River Remedial Action Plan

The rapids area of the St. Marys River between 1888 (A) and in 1990 (B)

Annual average flow of the St. Marys River in 1990 was 1.8 x10^3 m^3/s with the annual average flow distribution represented as percent next to the arrows.

(modified after Duffy et al. 1987, DFO, Sea Lamprey Control Data Files and International Lake Superior Board of Control 1991)





Industrial Use

Algoma Steel - 0.24%
St. Marys Paper - 0.02%

Domestic Use

Michigan and Ontario - 0.02%

In the late 1960's, the increased demand for water resulted in the concern that water levels over the rapids were not sufficient in order to maintain the aquatic biota (Duffy *et al.* 1987). In 1983 a literature study completed by Koshinsky and Edwards resulted in several proposals for remedial action that would ensure that the flow over the Rapids would be sufficient for the protection of aquatic biota and organisms. This study resulted in the construction of a strategically placed berm in 1985. The berm currently maintains the recommended water level over a portion of the rapids (Figure 5.3).

In addition to the Rapids modification, the increasing number and size of vessels navigating the St. Marys River resulted in the dredging and excavation of natural channels in the rivers' lower reach. Lower Lake George and East Neebish Rapids were dredged in 1857. In 1894, the shipping channel was changed to Lake Nicolet and the East Neebish Channel. Subsequent excavation of bedrock in the West Neebish Channel once again altered the main navigational route. In the 1920's all channels were deepened.

The locks at Sault Ste. Marie were open year round from 1974 through the winter of 1978-1979 as part of a feasibility study for extending navigation on the Great Lakes year round. Although the study successfully demonstrated that navigation times could be extended, recent declines in commodity demand have left the locks closed during the winter months post-1979. Several studies examining the impacts of winter navigation on the St. Marys River showed that drift rates of detritus, macrophytes, zooplankton and macroinvertebrates out of the system was accelerated during ice cover with vessel traffic (Poe and Edsall 1982). In addition, sedimentation and habitat destruction from scouring by vessel-induced wave and current action was increased with ice cover (Liston *et al.*, 1983).

5.1.3.3 Discharge Rates

Outflows from Lake Superior through the St. Marys River have been recorded since 1860. Figure 5.4 shows the mean flow rate for the 124 years of record is 2,144 m^3/s, while monthly rates have ranged between a low of 1,161 m^3/s in September of 1955, and a high of 3,597 m^3/s in August of 1944. Since completion of the Long Lac and Ogoki Diversions in the 1940's, in which some waters originally draining north to James Bay were diverted into Lake Superior, there has been an increase in mean annual flow rates of the St. Marys River, equal to about 196 m^3/s (or 8%).

Figure 5.5 shows the mean, maximum and minimum monthly flows between 1900 and 1978 (Duffy *et al.*, 1987). On average, flows are least in March (1,869 m^3/s), when Lake Superior levels are lowest, and greatest in September (2,379 m^3/s), when the lake level is highest.

5.1.3.4 Currents

St. Marys River currents are highly variable and influenced by the discharge from Lake Superior, and the water level of Lake Huron. In this regard, velocities are impeded by high surface water levels at the river's mouth at Lake Huron, by easterly or southerly winds, and/or by low barometric pressures. A high water level in Lake Superior results in greater discharge to the river, with corresponding increases in current velocities. Velocities are swiftest, up to 1.0 m/s, in constricted areas and navigation channels and are essentially nil through some nearshore wetlands. As a result, flushing time or throughput can vary considerably, from about 2 days to more than 13 days (Kauss 1991).

McCorquodale and Yuen (1987), showed that currents in Leigh Bay and Marks Bay (also known as Point aux Pins Bay), are low when compared to the shipping channel and are responsive to wind speed and direction. With no wind or prevailing NW winds, a weak counter-clockwise gyre occurs in Marks Bay. With ESE winds counter clockwise gyres develop in both Marks and Leigh Bays. Winds from the south and SW eliminate the gyres. Winds can also create seiches in the upper river which can result in increased turbidity.

Figure 5.4

St. Marys River Remedial Action Plan

Yearly average discharge of the St. Marys River at Sault Ste. Marie between 1860 and 1984

(from Duffy et al. 1987)

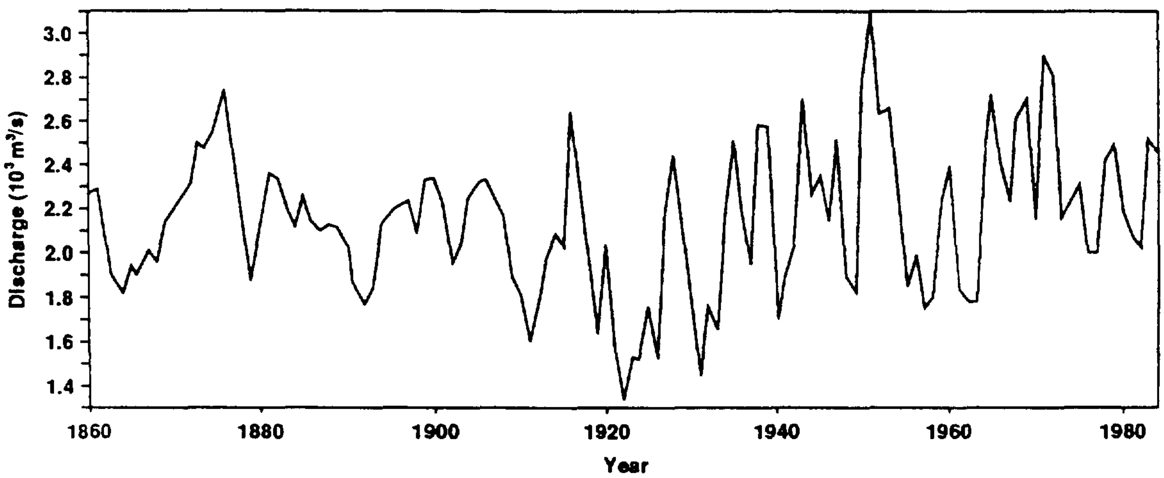
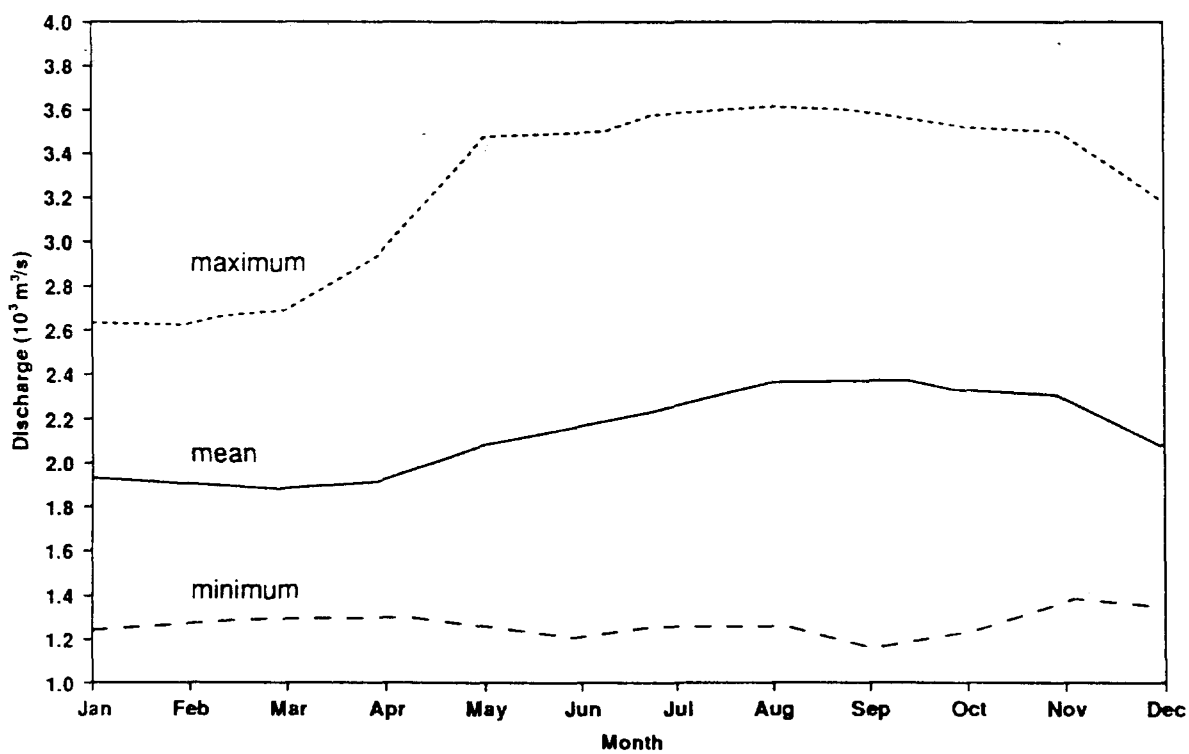


Figure 5.5

St. Marys River Remedial Action Plan

Monthly average discharge of the St. Marys River at Sault Ste. Marie during the period 1900 to 1978

(from Duffy et al. 1987)



In the lower St. Marys River, flows split at Sugar Island, with about 25% of the total flow discharging to the north via Lake George, and the remaining flow discharging south via Lake Nicolet. The flushing rate of Lake Nicolet has been calculated at 1.31 lake volumes per day between April and October, 1983 (Duffy *et al.*, 1987). This means that materials in solution or suspension would be transported through the St. Marys River in a matter of days. However, it should be noted that this is a generalization and caution should be taken when comparing differences in currents within the navigation channels and at sites closer to shore where areas of stagnation can prevail (Duffy *et al.*, 1987).

5.1.3.5 Water Level Fluctuations

Water levels of the St. Marys River are subject to three types of fluctuation:

- Seasonal: Are a result of variations in precipitation, evaporation and runoff, with the highest water levels occurring during the summer and lowest in the winter. These factors are compounded by the regulated monthly flows at Sault Ste. Marie. Water levels fluctuate an average 0.3 m annually.
- Long-Term: Are more extensive than seasonal changes, with a 1.2 m difference between the highest and lowest monthly mean levels in the upper St. Marys River and 1.5 m in the lower river over the last 80 years (Duffy *et al.*, 1987).
- Short-Term: Are typically caused by winds, sudden changes in barometric pressure, seiches and increased discharge of the river. Short-term fluctuations commonly cause water levels to fluctuate a few cm over several hours; however, a large fluctuation of 1.5 m within a three hour period has been recorded on the St. Marys River (Duffy *et al.*, 1987).

5.1.3.6 Vessel Passage

The passage of commercial cargo ships generate additional influences on the hydrology of the St. Marys River (Duffy *et al.*, 1987). The passage of a cargo ship creates a water cycle in which a standing wave is created which increases the water level and generates currents towards the shore. After these currents reach the shore and are directed back to the navigation channel, a drawdown of water occurs which increases current velocity. This drawdown continues until the current reverses itself and heads again towards the shore creating a surge. This cycle continues until current velocities diminish. Finally at the end of the cycle, water levels increase at the shore before returning to ambient conditions when the natural hydrology of the river is resumed. Water level fluctuations can range between 0.01 m and 0.7 m. and currents generated by ship passage can reach a speed of up to 1.0 m/s (Duffy *et al.*, 1987).

5.2 CLIMATE

5.2.1 Air Temperature

Average air temperatures range from -10.5°C in January to 17.5°C in July (Figure 5.6). Air temperatures are moderated throughout most of the year by Lake Superior. Based on recordings taken between 1951 and 1980, the average first day of 0°C in the Fall is September 27, and the average last occurrence in the Spring is May 26. The highest temperature on record, 36.7°C, occurred in 1888 (Duffy *et al.*, 1987).

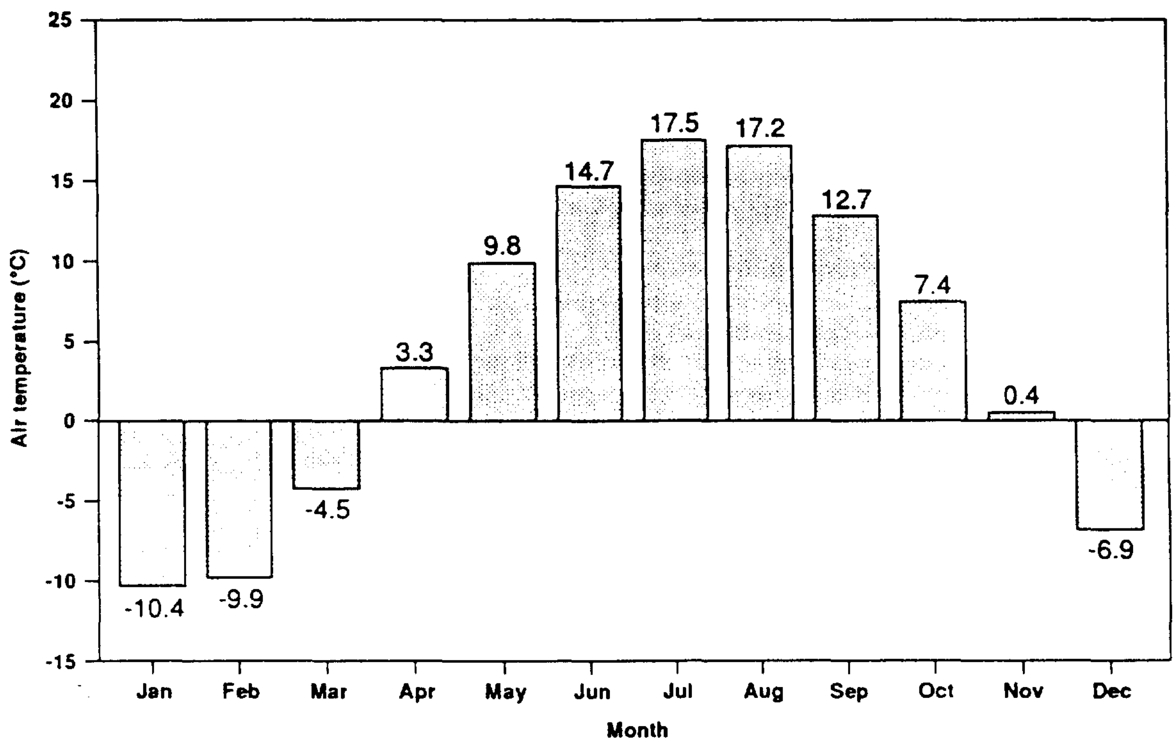
Figure 5.6

St. Marys River Remedial Action Plan

Mean monthly air temperature for Sault Ste. Marie, Michigan

The means are calculated over a 30-year period between 1951 and 1980.

(from Duffy et al. 1987)



5.2.2 Water Temperature

Temperatures of St. Marys River open waters are near 0°C for four months of the year and generally follow surface water temperatures of Whitefish Bay which range between 0°C from December through March to 16°C by mid-September. Shallow, nearshore areas (i.e. emergent wetlands) may have temperatures 1 to 6°C higher in the summer.

Ice forms on the St. Marys River with broad, shallow areas freezing first, followed by the deeper, faster reaches. Munuscong Lake usually freezed first in mid-December followed by Raber Bay and Izaak Walton Bay. The last sites to freeze over by mid-January are the faster reaches of the river at the north end of Lake Nicolet. Ice thickness varies considerable on the river. Ice break-up is the reverse of the freeze-up trends; that is, the faster, deeper areas tend to break-up earlier than the slower, shallower areas (Duffy *et al.*, 1987).

5.2.3 Precipitation

The following are 30-year (1951 to 1980) precipitation averages, expressed as water equivalents, and reported by Duffy *et al.* (1987), based on information collected at Sault Ste. Marie, Michigan, NOAA (1985).

- The annual mean is 85.0 cm;
- February is the driest month with a mean of 4.3 cm, while September is the wettest, with a mean of 9.9 cm;
- Minimum and maximum monthly averages were 0.4 cm and 24.1 cm for October, 1963 and August 1974 respectively; and
- Maximum precipitation in 24 hours ranged (on a monthly basis) between a low of 2.8 cm in February, 1977 and a high of 15 cm in August, 1974.

Total seasonal snowfall ranges from a minimum of 0.82 m (in 1899/1900) to a maximum of 4.54 m (1976/1977) (Duffey *et al.* 1987). On average, permanent snow cover begins on November 21 and remains until April 7.

5.2.4 Wind Patterns

Prevailing winds from the northwest and southwest blow across Whitefish Bay and into Sault Ste. Marie 40% of the time. Wind speeds average between 8 and 15 m/s. It is not known if these wind conditions extend over the entire length of the river (Duffy *et al.*, 1987). Light persistent winds, with speeds less than 4 m/s, are more frequent over land, particularly during the summer and fall when they occur 65% of the time.

Much of the St. Marys River shoreline is exposed to the prevailing winds and consequently wave and current action. In many areas there is little to no emergent vegetation and the shore and river bottom is comprised of rock or shifting sand. The development of emergent wetlands occur in more protected areas which are predominantly located on the lee side (western shore) of the prevailing winds (Duffy *et al.*, 1987).

5.3 TERRAIN

5.3.1 Geology and Geomorphology

Geological structures underlying the St. Marys River Valley have changed little since the post-glacial period about 11,000 years ago. Much of the bedrock of the basin consists of volcanic and granitic rocks of Precambrian origin in the north, and Ordovician and Silurian dolomites in the south (Duffy *et al.*, 1987).

The primary influence on surficial geology in recent times has been the fluctuating water levels. As recently as 3,000 years ago, crustal rebound lifted the rock ledges at Sault Ste. Marie to a level higher than the water level of Lake Huron. The net effect of this uplifting was to change the strait connecting Lake Superior to Lake Huron into the St. Marys River as it is today (Duffy *et al.*, 1987). The influence of fluctuating water levels over the last 4,000 years has been to erode surficial deposits, leaving remnant beaches and dunes, and other littoral features along the shores of the river.

The surficial geology of the southwestern St. Marys River is composed primarily of lacustrine sediments and end moraines (Figure 5.7). Level lakebed plains on the southwestern edge of the valley are interrupted by gently rolling plateaus, low rounded ridges, or remnant beach ridges, sand dunes, bluffs and marshlands. In Ontario, knobby Precambrian rock is partially covered by a thin layer of till or lacustrine clay, especially on the northeastern edge of the valley (Duffy *et al.*, 1987).

5.3.2 Relief

Relief in the northern part of the immediate St. Marys River watershed is distinctly rugged while the remainder is somewhat subdued. These differences in relief coincide with the distribution patterns of the underlying bedrock. Areas on both sides of the river that are underlain by sedimentary bedrock types are undulating to gently rolling, with occasional abrupt rises associated with small escarpments in the bedrock or raised shorelines. Areas in the northern and northeast part of the St. Marys River watershed are dominated by Precambrian bedrock that results in higher relief with a more irregular and knobby character.

5.3.3 Soils

The soils along the north shore of the St. Marys River strongly reflect the distribution of glacial and post-glacial deposits. Loosely consolidated sandy soils of varying depth occur from the outlet of Lake Superior to about the western end of Sault Ste. Marie. Similarly, coarsely textured soils derived from sand and gravel outwash occur near the mouth of the Garden River. Elsewhere, finer textured clay and silt loams predominate however, these soils are interspersed with local organic deposits which have accumulated in depressions, and bedrock outcroppings with shallow mantles. These classified mineral soils (Table 5.5) are similar on both sides of the river. They are highly retentive of water, as are the organic soils which are most common west and south of Munuscong Lake (Duffy *et al.*, 1987).

5.3.4 Terrestrial Vegetation

The vegetation of the study area has been classified as typical of the northern conifer-hardwood forest (Curtis 1959), the temperate forest (maple-beech-hemlock) biome of North America (Shelford 1963), and the Great Lakes-St. Lawrence forest region of Canada (Rowe 1972). The St. Marys River and its environs are included within the Algoma section of the Great Lakes-St. Lawrence forest region (Rowe 1972), which is characteristically dominated by sugar maple, yellow birch, red oak, ironwood, and white birch on well-drained sites. Conifers such as white pine, red pine, white spruce and balsam fir attain varying levels of co-dominance in these stands.

Poor to very poorly drained sites commonly support a vegetation cover that is often more boreal in character, with black spruce, tamarack, and white cedar being the major species. However, lowland hardwood stands of black ash, balsam poplar, and white elm are equally abundant.

Moist to wet marginal sites support a variety of minor plant communities, including lowland thickets of speckled alder, various willows, and sweet gale, marsh communities dominated by emergent species such as hardstem bullrush, burr reed, cattail, spikerush and wet meadows dominated by sedges, grasses and numerous other hydrophytic species.

Figure 5.7

St. Marys River Remedial Action Plan

Surficial geology of Eastern Upper Michigan and Northeastern Ontario

(from Duffy et al. 1987)

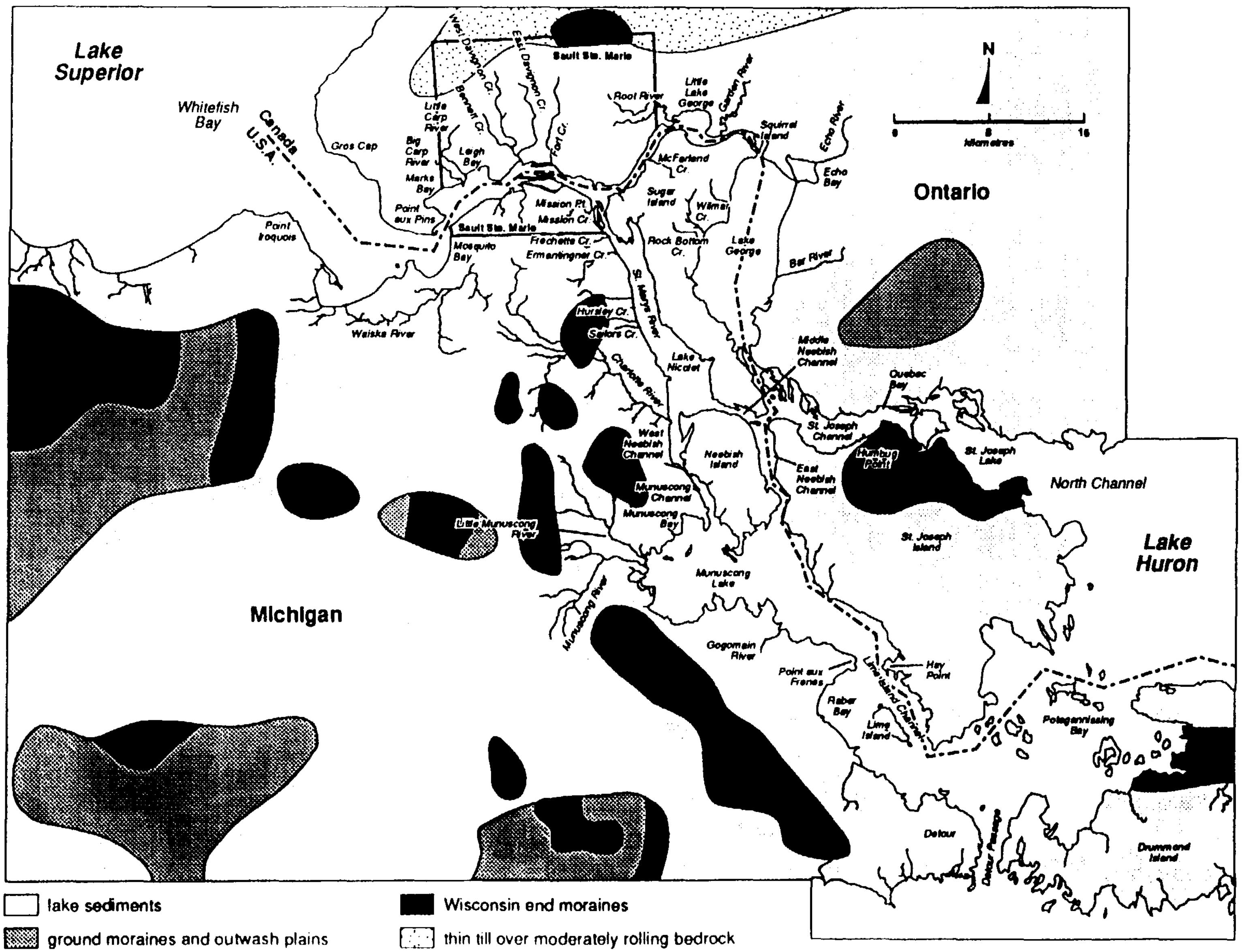


Table 5.5 Predominant soil types in eastern Chippewa County, Michigan and on islands within or lands adjacent to the St. Marys River (Duffy *et al.*, 1987).

Soil Type	Location						
	West Lake Nicolet	Sugar Island	Neebish Island	Sand Island	Munuscong Lake Area	De Tour Area	Drummond Island
Bergland silty clay loam	X		X		X		
Bruce fine sand loam	X				X		
Blue Lake sandy loam (stoney phase)					X		
Coastal beach	X	X	X	X	X	X	X
Carbondale muck					X		X
Detour stoney loam						X	X
Eastport sand						X	
Grandby sand							X
Johnswood stoney loam							X
Munising stoney loam	X	X					
Munising stoney sandy loam	X	X	X				
Newton sand				X			
Ontonagon clay							X
Ontonagon silty clay loam	X	X	X				
Rock outcrops			X			X	X
Spaulding peat					X		
Strongs loamy sand					X		
Tahquamenon peat				X			

5.4 LAND USES

5.4.1 Undeveloped Lands

Most lands within 5 km of the St. Marys River shoreline are undeveloped forest and wetlands which provide habitat for fish and wildlife. These lands total approximately 163,000 ha, which represents about 83% of the total area in the St. Marys River immediate watershed.

5.4.2 Agriculture

Agricultural production in the St. Marys River Valley is limited by a growing season which averages 134 days per year, and generally shallow, poorly-drained soils (Duffy *et al.*, 1987). Agriculture focuses on dairying and beef production, with hay being the dominant crop. Approximately 140,000 ha of the St. Marys River valley in both Ontario and Michigan is under cultivation (Duffy *et al.*, 1987). Table 5.6 outlines the agricultural characteristics on the Michigan side of the St. Marys River. Equivalent information for Ontario is not available.

Table 5.6 Agricultural resource characteristics for the Michigan side of St. Marys River valley (UGLCCS Nonpoint Source Workgroup 1987).

Feature	Description
Total land area	203,546 ha
Land in farms	19,836 ha
Area in farms	9.7 %
Cattle and calves	4,167
Milk cows*	1,186
Hogs and pigs	374
Sheep and lambs	950
Poultry	--
Corn	89 ha
Wheat	124 ha
Soybean	0 ha
Hay	7,154 ha
Vegetables	6 ha
Orchard	4 ha

*Included under cattle and calves

5.4.3 Urban and Rural Residential

About 5% or 10,000 ha of the lands within 5 km of the St. Marys River shoreline have been urbanized. The main centres, Sault Ste. Marie, Michigan and Sault Ste. Marie, Ontario are located in the upper reach and rapids area of the St. Marys River with populations of 14,000 and 81,000 respectively.

The population of Sault Ste. Marie, Michigan declined from 16,240 in 1976 to 13,960 in 1986, at an average rate of 1.4% per year. In the same period, the population of Sault Ste. Marie, Ontario decreased very slightly. From 1976 to 1981 the population increased at a rate of 0.41% per year, but declined at about the same rate to 80,905 in 1986 (Table 5.7).

Smaller hamlets of Garden River, Echo Bay and Echo River are located downstream of Sault Ste. Marie, Ontario. There are also two Indian Reserves, Rankin Location and Garden River Indian Reserve. 1986 on-reserve populations were 386 and 821, respectively. Permanent and considerable seasonal residential development occurs along portions of the mainland and island shorelines, on both sides of the river. There appears to be a trend along the Ontario shoreline to turn summer cottages into year-round residences.

5.4.4 Industry

Two major industrial developments, steel and paper making, were established in the early 1900's in Sault Ste. Marie, Ontario. The dominant manufacturing industry is the Algoma Steel Corporation's integrated steel mill. During the 1970's, this operation employed about 10,000 people. However, employment levels have since declined. The St. Marys Paper Company is also located in Sault Ste. Marie, Ontario, and employs about 450 people (Duffy *et al.*, 1987). There are no other major industries along either side of the river, although some minor light industries, mainly secondary manufacturing supporting the steel and paper industries, exist in Sault Ste. Marie, Ontario.

Table 5.7 Population densities for Sault Ste. Marie, Michigan and Sault Ste. Marie, Ontario and the Rankin Location and Garden River Indian Reserves.

	Population			Change (% per year)		
	1976	1981	1986	1976-1986	1976-1981	1981-1986
Sault Ste. Marie, Michigan	16,240	14,337	13,960	- 1.40	- 2.34	- 0.53
Sault Ste. Marie, Ontario	81,048	82,697	80,905	- 0.02	+ 0.41	- 0.43
Rankin Location Indian Reserve		333	386			+ 3.1
Garden River Indian Reserve		725	821			+ 2.6

Copper, lead and silver have been mined in the St. Marys River Valley and dolomite has been quarried on East Neebish Island (Duffy *et al.*, 1987),. For many years a sand and gravel company, A.B. McLean Ltd. extracted aggregates (approximately 20,000 m^3 per year) from the St. Marys River, with facilities located in downtown Sault Ste. Marie, Ontario. A.B. McLean Limited is currently extracting aggregates from a 567 ha plot in Whitefish Bay, immediately offshore from Pointe aux Chenes. The company holds a licence issued by the OMNR to extract about 60,000 m^3 of aggregate annually, provided that no removal is carried out in areas less than 3.66 m below datum for Lake Superior (183 m above sea level). In 1986, A.B. McLean Ltd. applied to expand its operations over a five year period according to the following schedule:

1987 - 200,000 m^3
1988 - 300,000 m^3
1989 - 400,000 m^3
1990 - 500,000 m^3

According to B.A.R. Environmental (1988), a temporary licence was granted to extract 200,000 m^3 in 1987; however, only 25,000 m^3 of material was actually removed. In connection with a study to evaluate the effects of sedimentation on Lake Whitefish spawning grounds, a temporary licence to excavate 200,000 m^3 was again granted in 1988. Approximately 150,000 m^3 of material was removed. The 1990 permit has been issued by the Ontario Ministry of Natural Resources.

5.4.5 Waste Disposal Sites

5.4.5.1 Michigan

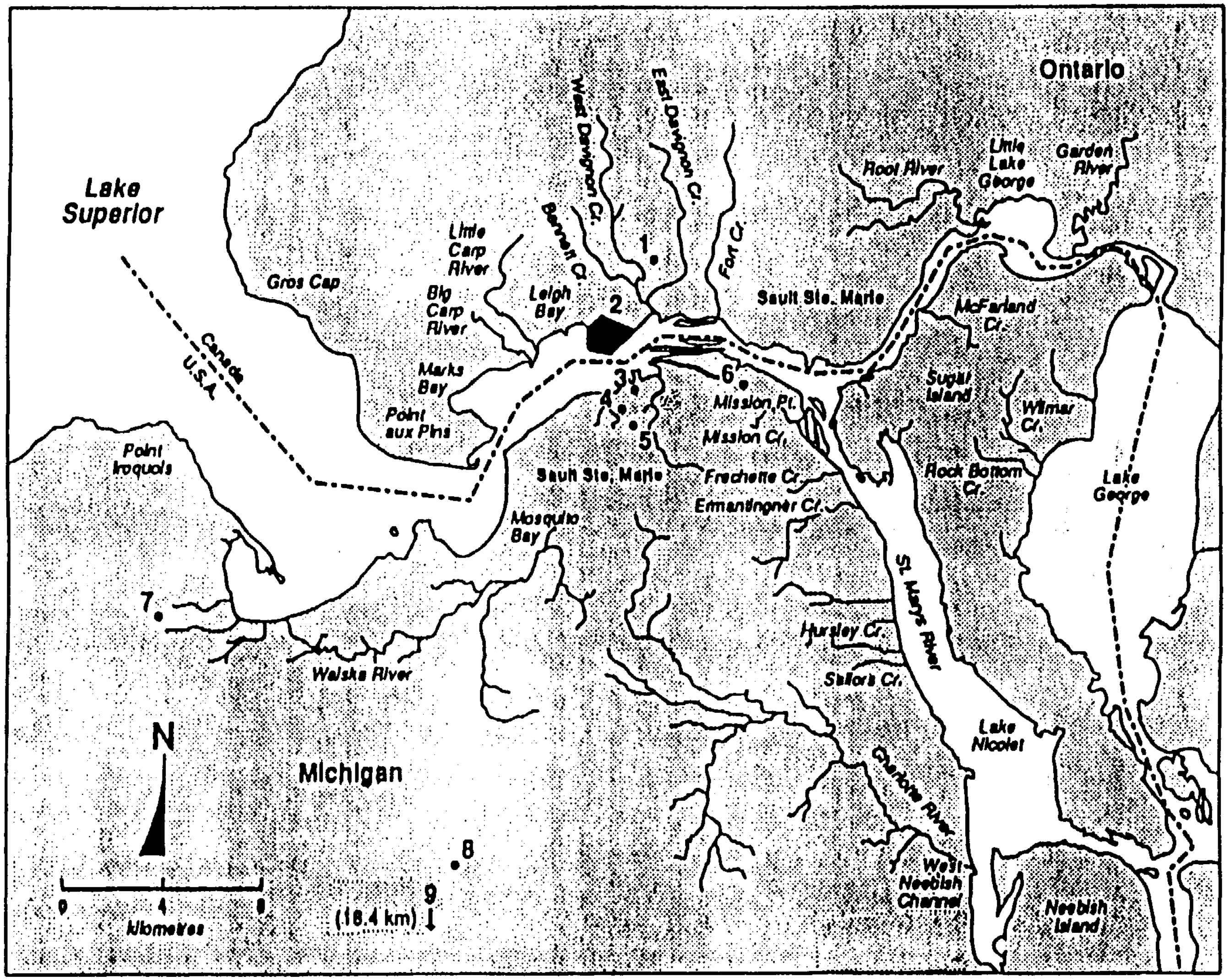
There are three municipal, four industrial waste disposal sites and one site of environmental concern within the immediate watershed of the St. Marys River AoC (Figure 5.8).

The municipal sites include the Dafter, Bay Mills and Superior Sanitation-Rudyard Landfills. The Dafter landfill is currently the only active site. Bay Mills was closed in mid 1991 and Superior Sanitaion-Rudyard was closed in early 1990. The Anderson Corporation has purchased the Superior Sanitation-Rudyard site and installed monitoring wells and a new leachate collection system in order to reopen the site. Both the

Figure 5.8

St. Marys River Remedial Action Plan

Location of waste disposal sites in the immediate watershed of the St. Marys River Area of Concern



1 Sault Ste. Marie (Cherokee) Landfill
2 Algoma Steel Slag Dump
3 Cannelton Industries Tannery Disposal Site
4 Soo Line Railroad Solid Waste Site
5 Superior Sanitation 3 Mile Site
6 Sault Ste. Marie (Union Carbide) Disposal Site
7 Bay Mills Township Landfill
8 Dafter Landfill
9 Superior Sanitation - Rudyard

Dafter and Bay Mills sites have monitoring wells for the detection of groundwater contamination. These three sites were licensed to take domestic and general municipal wastes, light industrial refuse and sludge from local wastewater treatment plants.

Three industrial waste disposal sites (all closed), the Cannelton Industries Site, Sault Ste. Marie Disposal (Union Carbide) and the Superior Sanitation 3 mile site are on Michigan's Priority List for Evaluation and Interim Response (Act 307 List). The Cannelton Industries Site is also a federal Superfund Site.

The Cannelton Industries site was the location of the former Northwestern Leather Company, a tannery which operated from 1900 to 1958. About 0.4 ha of the site is characterized by multi-coloured soils devoid of vegetation. Soils on site contain elevated levels of arsenic, cadmium, chromium, copper, lead, zinc and cyanide.

Sault Ste. Marie Disposal (Union Carbide) is a waste pile approximately 800 m long and 45 m high, unlined and uncovered. The wastes are from Union Carbide's production facility. Wastes are predominantly calcium carbonates with minor amounts of heavy metals and cyanide, along with varying amounts of demolition debris (MDNR 1989).

The Superior Sanitation 3 mile site contains municipal and light industrial refuse and is now closed. This landfill is covered with a clay cap and six monitoring wells were installed. Based on limited monitoring data, there seems to be an effect on groundwater due to the landfill, but the degree of contamination is unclear. The fourth industrial disposal site is the Soo Line Railroad Solid Waste site. It is located approximately 800 m from the St. Marys River and contains construction and demolition debris, trees, stumps and other inert wastes.

The former 753 Radar Station is an area of environmental concern. It is an Act 307 site because of groundwater contaminated with lead, PCE, TCE and TCA. The USACOE is responsible for the site, and has produced a hazardous and toxic waste evaluation and is proceeding with site cleanup.

5.4.5.2 Ontario

There are two waste disposal sites on the Ontario side of the St. Marys River, the Algoma Steel Corporation Limited's Slag Dump Area and the City of Sault Ste. Marie's Landfill (Cherokee) site (Figure 5.8).

The Algoma Steel Slag Site is a 328 ha licensed disposal facility, adjacent to the St. Marys River at the west end of Sault Ste. Marie, which has been in operation since 1910. The predominant material deposited at the site is primarily waste slag from iron and steel operations. However, lime, industrial refuse, waste acid and oil, coke oven gas condensate, and sludge are also disposed on the site (Beak 1988). According to LaHaye (pers. comm.) oil and coke oven gas condensate are no longer disposed of at the slag dump. In total, approximately 718,600 tonnes of solid waste and 66,800 tonnes of liquid waste are disposed of annually. Several investigations have indicated the presence of numerous contaminants beneath and adjacent to the site. Beak Consultants have carried out contamination studies from 1988 through 1990. Groundwater samples were analyzed for the following parameters: DIC, alkalinity, Cl, Br, F, SO_4, NO_3, sulphide, cyanide, Ca, Mg, Na, K, Zn, Cd, Mn, Co, Cu, Fe, Pb, Cr, Ni, Be, Mo, Ca, Ba, Al, Sr, As, Se, Hg, NH_3, TKN, total P, DOC, oil and grease, PCBs, VOCs, BTX and PAHs. The final report on their findings has yet to be released.

The Cherokee Landfill is a 56.6 ha site northeast of Sault Ste. Marie, Ontario. Wastes deposited at the site are approximately 60% domestic (200 tonnes/day), 10% commercial (35 tonnes/day), and 30% sewage sludge (100 tonnes/day). A proposed expansion of the site to 88.6 ha has resulted in an ongoing environmental assessment.

5.5 WATER RESOURCE USES

5.5.1 Shipping

According to Duffy *et al.* (1987), the number of ship passages between 1970 and 1981 ranged between a high of 13,991 in 1973 and a low of 11,059 in 1977. However, the number of passages has decreased in recent years due to older smaller ships being replaced by newer, larger ones, and lower costs of overland transportation. In 1986, only 8,345 vessels passed through the locks. These vessels carry mainly crude oil, grain, steel, coal, petroleum products, taconite and iron ore between Lake Superior and the industrial centres of the lower lakes. The total amount of cargo (metric tonnes) passing through the St. Marys River from 1987 to 1989 is listed as follows (R. Quick, Canadian Coast Guard, pers. comm.):

1987 345,099 metric tonnes, 4% of the total volume of petroleum products shipped in the Great Lakes Region (including Canada and U.S. shipments)

1988 364,128 metric tonnes, 3% of the total volume of petroleum products shipped in the Great Lakes Region (including Canada and U.S. shipments)

1989 469,791 metric tonnes, 4% of the total volume of petroleum products shipped in the Great Lakes Region (including Canada and U.S. shipments)

Shipping is suspected to be a vector for the accidental introduction of some exotic species, i.e. zebra mussels, into the Great Lakes.

5.5.2 Water Supply

The St. Marys River is the source of drinking water for just over 96,000 people through municipal intakes in the upper river at Big Point, Michigan and Gros Cap, Ontario, as well as numerous communal and private intakes along its entire 120 km length. The rated capacity and average consumption volume for the Michigan water filtration plant is 15×10^3 m^3 per day and 9.5×10^3 m^3 per day, respectively. Construction of a new water filtration plant is scheduled for 1991. The new plant will have a design capacity of 22.7×10^3 m^3 per day.

The Ontario water filtration plant obtains approximately 50% of its water from Whitefish Bay at Gros Cap and the remaining 50% from 6 wells drawn from 2 aquifers north of Sault Ste. Marie (Public Utilities Commission, Sault Ste. Marie, Data Files). The amount of water from each source varies depending upon demand, cost and availability (i.e. well repair). The water intake from the St. Marys River was moved to Gros Cap in 1987 in order to be removed from shipping and contaminant discharges. The water filtration plant has a base design capacity of 40×10^3 m^3 per day and can supply water at rates ranging from 17×10^3 m^3 per day to 60×10^3 m^3 per day. A finished water storage reservoir (15,000 m^3) and two in-ground storage tanks (33,000 and 10,000 m^3) can provide an increased water supply if required.

The river also serves as a supply for cooling and processing water for Algoma Steel and St. Marys Paper. Up to 93% of the river's flow is allocated to the generation of hydroelectric power at the United States Corps. of Engineers and the Sault Edison Electric Company plants in Michigan, and the Clerque Generating Station in Ontario (Figure 5.3).

5.5.3 Industry

Two major industries in Ontario, Algoma Steel Corporation and St. Marys Paper, use water from the St. Marys River for cooling and processing. Figure 5.3B shows that Algoma Steel utilizes 0.24% and

St. Marys paper uses 0.02% of the rivers' total flow. Both facilities discharge treated wastewater to the St. Marys River.

5.5.4 Wetlands

Coastal wetlands exist along much of the lower St. Marys River (Figure 5.9), where a lack of wind or waves allows a fine-grained substrate to develop. These provide habitat for fish, waterfowl and wildlife, and recreational opportunities.

Herdendorf *et al.* (1981) identified 76 wetland sites totalling 1,460 ha along the U.S. shoreline. Emergent wetlands are often stands of single species such as hardstem bullrush, burr reed, or spikerush. Single species stands represent about 65% of emergent wetlands, with mixed stands comprised mainly of hardstem bullrush and spike rush making up an additional 19% (McNabb *et al.*, 1986). Openings in emergent stands account for 15% of total wetland areas.

Submerged plants occur as a low understorey in emergent areas, and also throughout the emergent wetlands where substrate and water clarity permit attachment and growth (Duffy *et al.*, 1987). Twenty-eight species have been recorded (Liston *et al.*, 1986 and McNabb *et al.*, 1986) however, two charophytes and quillwort dominate the biomass. The submerged species tend to colonize the river bed from the edge of the navigation channel shoreward to about the 2 m depth contour, except on substrates of cobble, rock and shifting sand (Edsall *et al.*, 1988).

Coastal wetland sites on the Ontario side of the upper river are restricted to the mouth of the Little and Big Carp Rivers, since suitable substrate is largely absent throughout the remaining areas in Marks Bay, Leigh Bay and Whitefish Bay. In the lower river, wetlands exist as small pockets between cottage lots and other developed areas. Large wetlands occur at Echo Bay, Pumpkin Point, Bell's Point and Lake George (Figure 5.9).

5.5.5 Fish and Wildlife Habitat

5.5.5.1 Fish Habitat

Duffy *et al.* (1987) has identified four primary habitats in the St. Marys River. Each habitat supports a collection of fish species which distinguishes it from other habitats (Table 5.8). The habitats are as follows:

(1) open-water and embayments;
(2) emergent wetlands;
(3) sand and/or gravel beaches; and the
(4) St. Marys Rapids.

Channel characteristics significantly influence the composition of the sediments within these habitat types. For example, coarse materials are present in the rapids and other stretches exposed to currents, whereas sand and gravel beaches prevail where currents are reduced. As explained by Krishka (1989), fine sediments tend to settle out along reaches which are protected from wind and wave action, thereby allowing the establishment of numerous wetlands.

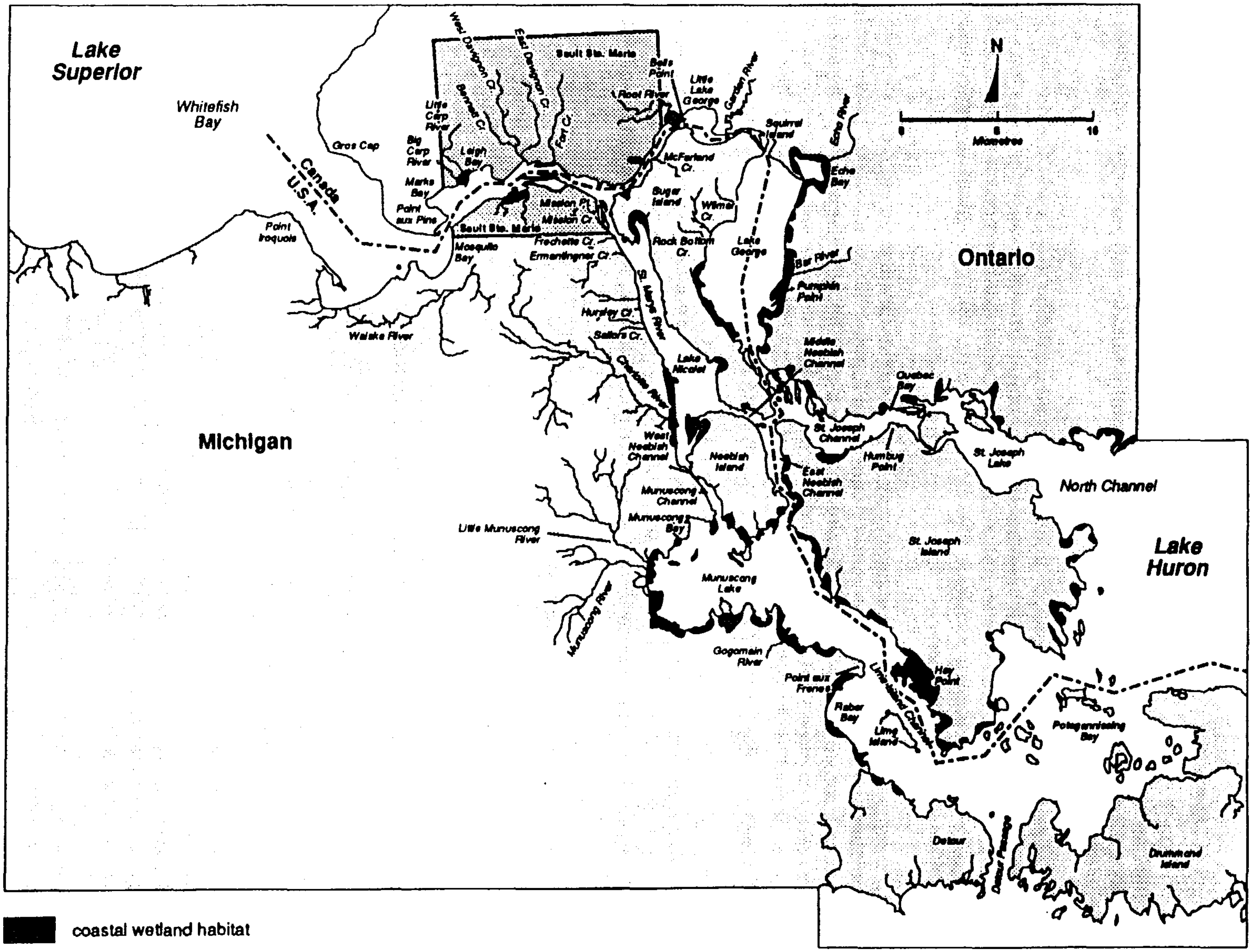
Fish species associated within each habitat are listed in Table 5.8. The information in Table 5.8 was compiled mainly from a survey carried out by Liston *et al. (1986)* in which sampling was done during every season in 1982 and 1983. It must be noted that apparent changes in species composition or abundance can occur if sampling is done at different times of the year in different surveys.

Figure 5.9

St. Marys River Remedial Action Plan

Location of coastal wetland sites along the St. Marys River

(prepared from Canada-U.S. 1987, OMNR Data Files)



coastal wetland habitat

Table 5.8 Predominant fish species in the primary habitats of the St. Marys River (Kauss 1991).

Species	Habitat			
	Open-water and Embayments	Emergent Wetlands	Sand and Gravel Beaches	St. Marys Rapids
Bowfin		L,J		
Lake sturgeon*	A			
Longnose sucker				A
White sucker	A,L,J			A
Bluegill		L,J		
Smallmouth bass	A	A,L,J		
Black crappie	A			
Gizzard shad		A		
Mottled sculpin	A			
Slimy sculpin				A
Carp		L		
Emerald shiner		A,L	A	
Common shiner		A,L	A	
Spottail shiner	A	A,L	A	
Mimic shiner	A	A,L	A	
Bluntnose minnow		A,L		
Longnose dace				A
Northern pike	A	A,L,J		
Burbot	J			
Ninespine stickleback	A			
Brown bullhead		J		
Longnose gar		J		
Rainbow smelt	A,L			
Johnny darter	A			
Yellow perch	J	A,J,L		
Walleye	A	A	J	A
Trout-perch	A		A	
Sea lamprey				A,L
Lake herring*	A			A
Lake whitefish	A			A
Rainbow trout				A
Brown trout				A
Brook trout				A
Lake trout				A
Pink salmon	A			
Chinook salmon	A			A
Central mud minnow		L		

Sources: Liston *et al.* as cited in Duffy *et al.* (1987)
* On Michigan threatened species list
A Adult
J Juvenile
L Larva
Note 1: Apparent changes in species composition or abundance can occur if sampling occurs at different times of the year in different surveys.

Many fish species are associated with more than one habitat, either as they mature from larvae to adult or as they move among habitats on a diurnal or seasonal basis. As well, large fish species tend to be associated with open water habitat, while smaller species are prominent near the bottom or in vegetation. Each type of habitat zone is distinctive in its species composition and/or species' relative abundance (Krishka 1989). Specifically, certain species such as golden shiner, lake chub, longnose dace and logperch are largely associated with one particular habitat type, while species such as white sucker, trout-perch, rainbow smelt and yellow perch occur within most habitats, although a preference may be apparent.

Open water areas of the river provide a wide variety of habitats, mainly for bottom-dwelling and open-water species. Embayments, as well as tributaries, are also important spawning and nursery areas (Goodyear *et al.*, 1982). The known (historical and contemporary) spawning areas of three major species, lake whitefish, lake herring and walleye, in the St. Marys River are shown in Figure 5.10.

As described by Kauss (1991), emergent wetlands serve as spawning, nursery and feeding areas for 44 species of fish, including all of the centrarchids, yellow perch, northern pike, bowfin, longnose gar, brown bullhead, and cyprinids, as well as other species. Adult fishes such as walleye and yellow perch, move into these areas on a diurnal basis to forage or rest.

Beach habitat is used by fish species which are common to nearby wetlands and open-water areas, with trout-perch and several species of shiner dominating (Duffy *et al.*, 1987). In this regard, Liston *et al.* (1980) identified 26 species from beach seine samples taken in the Middle Neebish Channel. Only a few species including trout-perch and spottail shiner use beach shoreline for reproduction. Nonetheless, beaches provide important habitat for many species which are forage for walleye, northern pike and other important gamefish within the St. Marys River.

The fish community in the St. Marys Rapids is different from communities using other parts of the river. Coho salmon, chinook salmon, Atlantic salmon and pink salmon generally migrate upstream to use the rapids during the fall spawning runs. Some coho tend to stay in the river year round. The rapids also provide important spawning habitat for rainbow trout, lake whitefish, lake sturgeon, brook trout, slimy sculpin and walleye (Kauss 1991). Abundant forage species are also found in the rapids and are dominated by longnose dace and slimy sculpin.

Up to 25 ha of rapids in the Whitefish Channel is subject to dewatering, with attendant adverse impacts on fish habitat and productivity, and benthic macroinvertebrates (Koshinsky and Edwards, 1983). In 1985, a berm was constructed along the Canadian side of the rapids and parallel to Whitefish Island (Figure 5.3). The Clerque Generating Station (Ontario), and Sault Edison Electric Company (Michigan) jointly contributed $1.2 million to construct the facility.

The plan was that a suitable flow rate is maintained within the bermed area, controlled by the first gate of the compensating works. A constant source of flow was also provided for Whitefish Island Channel by piping water through the Canadian lock wall. A minimum one-half gate remains open for the remainder of the rapids south of the berm, in accordance with the 1955 Modified Rule of 1949 of the International Lake Superior Board of Control (Krishka, 1989). However, the reduction allows large areas of the river bed to be dewatered on the U.S. side and creates inadequate flow velocities on the Canadian side.

5.5.5.2 Sea Lamprey Habitat

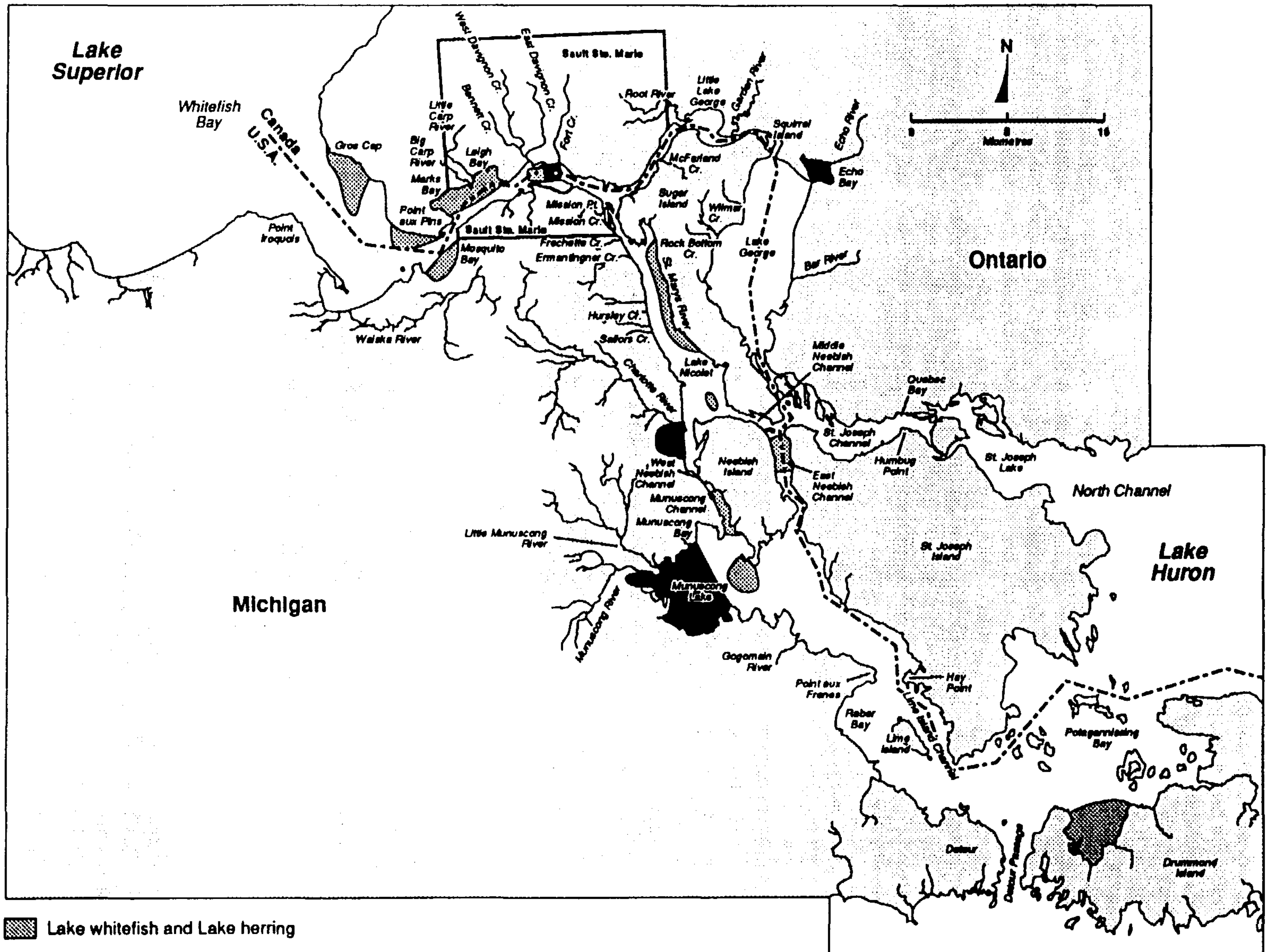
The sea lamprey is one of the many accidentally introduced species now thriving in the Great Lakes (Duffy *et al.*, 1987). Introduced into the upper Great Lakes after the opening of the Welland Canal in 1929, the first report of sea lamprey in Lake Huron was made in 1932 (Lamsa *et al.*, 1980). In 1962, the first larval sea lamprey were found in the St. Marys River (DFO/USFWS, Sea Lamprey Control Office, Data Files).

Figure 5.10

St. Marys River Remedial Action Plan

Location of lake whitefish, lake herring and walleye spawning areas in the St. Marys River

(prepared from Goodyear et al. 1982, Behmer et al. 1980)



Lake whitefish and Lake herring

Walleye

The St. Marys Rapids and other areas of the river and its tributaries with gravel or rubble substrate provide excellent spawning habitat for sea lamprey. Larval lamprey, termed ammocoetes, leave the nest by August and drift downstream, settling into soft silt or mud substrates where they burrow head first to establish a burrow from which they emerge to filter diatoms and algae from the water. Ammocoetes live for 3 to 17 years (Goodyear *et al.*, 1982) before metamorphosing into the parasitic stage after which they move into the Great Lakes to feed on the blood of fish for 1 to 1.5 years. Adults then return to spawn after which they die.

The Canadian Department of Fisheries and Oceans sea lamprey assessment traps fished at the Clerque Generating Station and the U.S. Fish and Wildlife Service traps fished at the Corp of Engineers Power Plant, have estimated adult populations during the annual spawning run since 1976. Population estimates are based on the mark-recapture method of adult lamprey at the Rapids. Figure 5.11a shows that the number of adult sea lamprey have steadily increased from a low of 16,812 in 1986 to almost 27,000 in 1989 (DFO/USFWS, Sea Lamprey Control Office, Data Files). Ongoing mark and recapture of larval sea lamprey by DFO/USFWS's Sea Lamprey Control section have estimated the number of ammocoetes in the St. Marys River be approximately 6.8 million within 6,698 ha (1,015/ha) (DFO/USFWS, Sea Lamprey Control Office, Data Files). Figure 5.11b shows their habitat covers a major portion of the river, particularly the Rapids area, the Sugar Island North Channel and Lake Nicolet.

5.5.5.3 Wildlife Habitat

The St. Marys River has an abundant supply of diverse riparian bird habitat. One hundred and eighty-six species of waterfowl, colonial waterbirds, shorebirds, passerines and raptors inhabit the area, as residents or as temporary inhabitants. As well, the river is an important staging and migration corridor for dabbling ducks, diving ducks and geese (Figure 5.12). These wetlands occur between the wetlands of Lake St. Clair and Long Point to the south and the rich wetlands of northwest Ontario. Wetlands of the St. Marys River are part of a series of feeding and resting areas utilized by waterfowl while migrating to and from their prairie beeding and southern wintering areas. Ice-free areas in the rapids along the Sault Ste. Marie, Ontario shoreline, and near the outflow of Sault Edison Canal in Michigan are used by over-wintering mallards, black ducks, Canada geese, common goldeneye, common mergansers, and greater and lesser scaup (Duffy *et al.*, 1987).

The river provides breeding, nesting, and rearing habitat for mallards, common mergansers, wood ducks, black ducks, Canada geese, common goldeneye, blue-winged teal, American widgeon, American coot, northern pintails, ring-necked ducks and common loons. Colonial water birds nesting on the many islands and in the marshes along the banks of the river include ring-billed gulls, common terns, double-crested cormorants, great blue herons, black terns, herring gulls and black-crowned night herons (Duffy *et al.*, 1987, Figure 5.13).

Raptors found in the vicinity of the St. Marys River include the northern bald eagle, osprey, snowy owl, great gray owl, gyrfalcon, peregrine falcon and burrowing owl. Duffy *et al.* (1987) indicated that these species are attracted to the river by its habitat diversity. More specifically, northern bald eagles were observed to nest in two locations on Sugar Island but the number of active nests has remained between one and two from 1974 to 1985. The number of active osprey nests increased dramatically between 1977 and 1982, stabilizing at 15 to 16 nests (Figure 5.14).

When water levels are low for extended periods, 'openland/grassland' terrestrial species, such as sharp-tailed grouse, can be found using the large expanses of sedge meadow adjacent to the river (G. Soulliere, MDNR, pers. comm.)

Figure 5.11a

St. Marys River Remedial Action Plan

Population estimates of adult sea lamprey from 1985 through 1989

Estimates made through the mark and recapture method at the Clergue Generating Station and the U.S. Army Corps of Engineers hydroelectric plant during spawning

(from DFO, Sea Lamprey Control Data, Files)

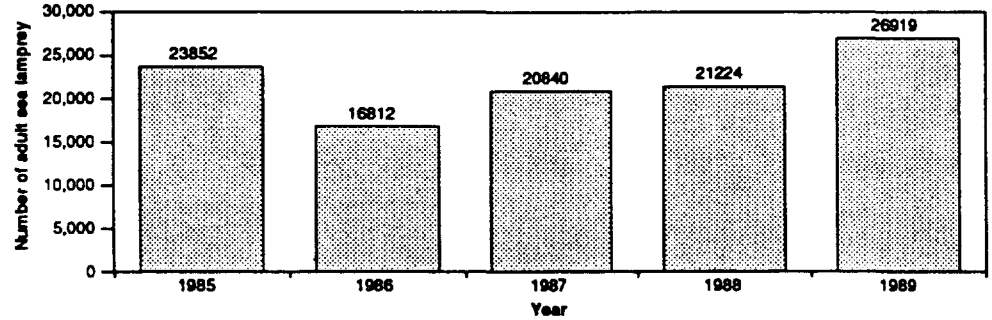
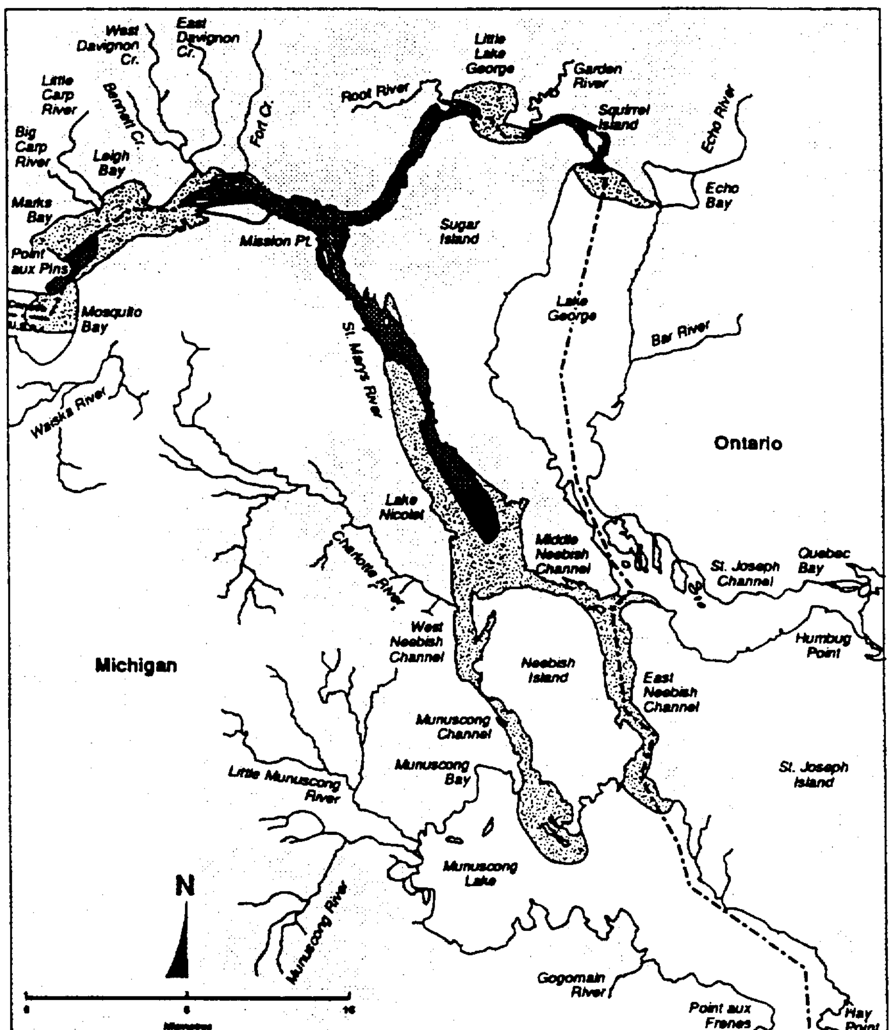


Figure 5.11b

St. Marys River Remedial Action Plan

Spatial distribution of larval sea lamprey (ammocoetes) in the St. Marys River, 1990

(from DFO, Sea Lamprey Control Data, Files)



Larval distribution and density

Named tributaries are, or have been, sea lamprey producers

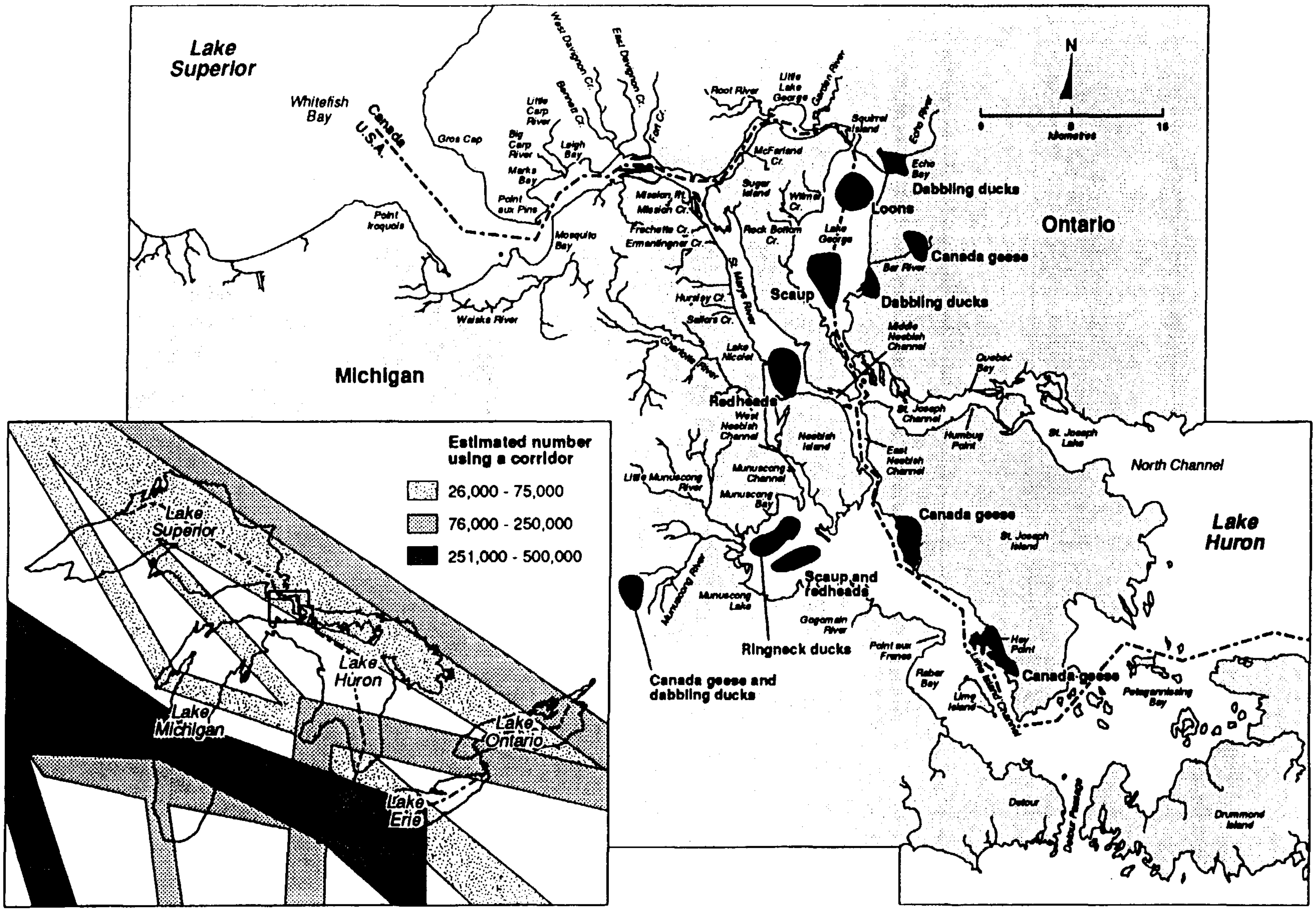
- moderate to high density
- low density
- no larvae found

Figure 5.12

St. Marys River Remedial Action Plan

Areas of waterfowl congregation in the St. Marys River during spring and fall

Concentrations of dabbling ducks inland are only during the spring. The inset shows migration corridors for diving ducks in the Great Lakes.
(from Duffy et al. 1987)



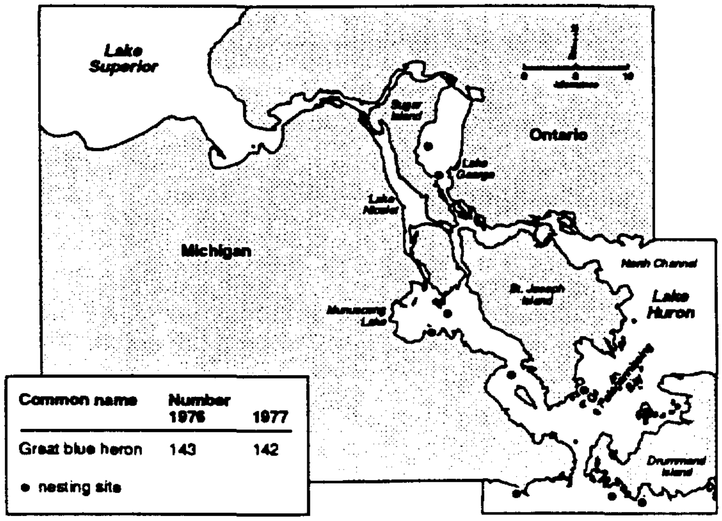
area of waterfowl congregation

Figure 5.13

St. Marys River Remedial Action Plan

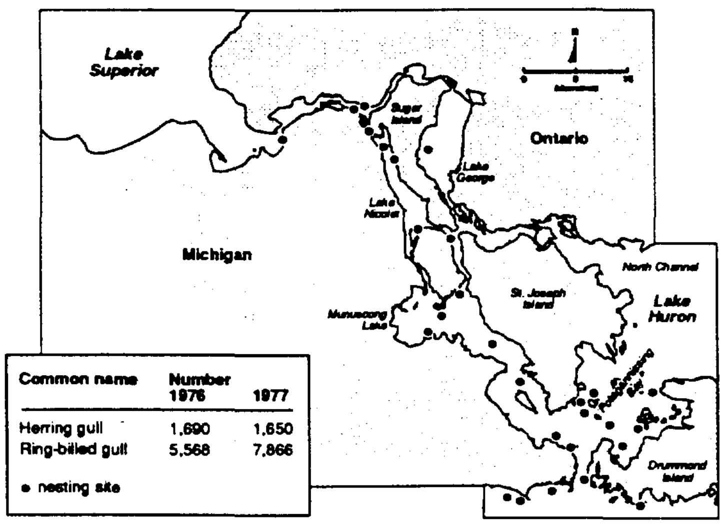
Nesting sites of selected colonial waterbirds in the St. Marys River and their estimated numbers in 1976 and 1977

(from Duffy et al. 1987)



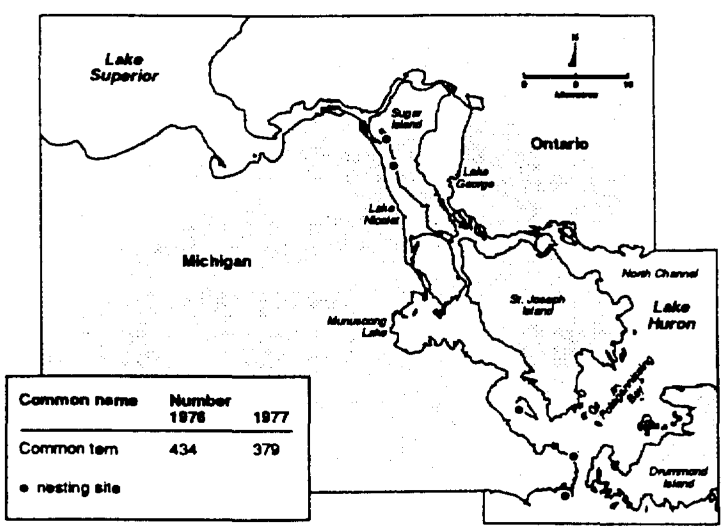
Common name	Number 1976	1977
Great blue heron	143	142

• nesting site



Common name	Number 1976	1977
Herring gull	1,690	1,650
Ring-billed gull	5,568	7,866

• nesting site



Common name	Number 1976	1977
Common tern	434	379

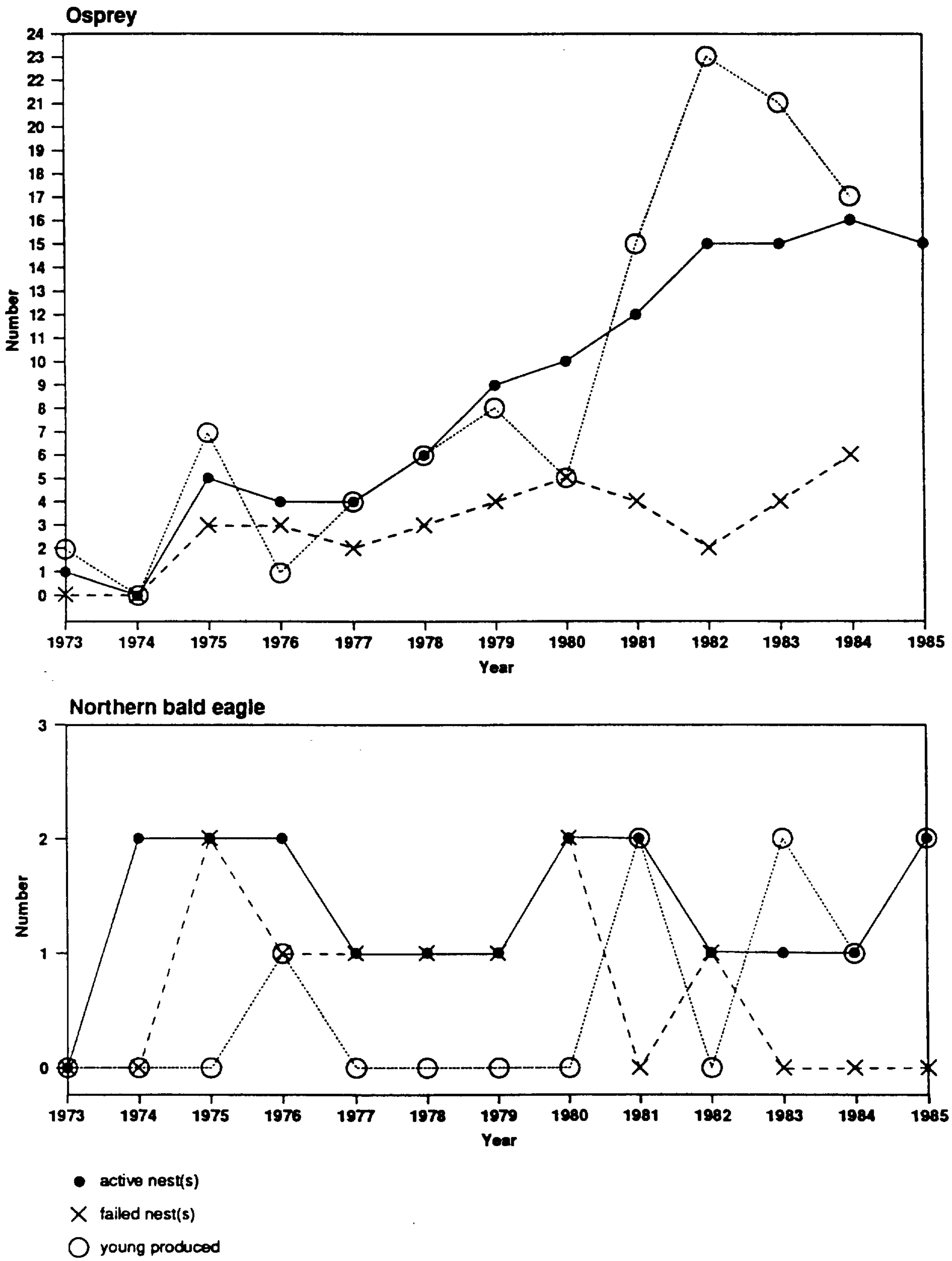
• nesting site

Figure 5.14

St. Marys River Remedial Action Plan

Number of active and failed osprey and northern bald eagle nests and young of each produced from the St. Marys River area during 1973 through 1985

(from Duffy et al. 1987)



Riparian shorelines of the St. Marys River provide excellent habitat for a variety of small mammals including beaver, otter, muskrat, mink, raccoon, American water shrew and northern water shrew. Although quantitative data are lacking, muskrat are perhaps the most common, and the two species of shrews may also be abundant.

The most common large mammal is the white-tailed deer, even though it is not abundant on the Ontario side of the river (Duffy *et al.*, 1987). Recent studies estimated that between 700 and 1,100 deer winter in a "deer yard" on Neebish Island, with fewer than 100 in another yard northwest of Sault Ste. Marie, Ontario (Duffy *et al.*, 1987). The distribution of critical white cedar habitat suggests that white-tailed deer should be even more abundant in the southern part of the AoC than current numbers suggest (Duffy *et al.*, 1987 and Figure 5.15).

In Michigan's Chippewa County, observational records suggest that the white-tailed deer population increased during the middle to late 1980's compared to the 1970's (Table 5.9).

Table 5.9 Relative abundance of white-tailed deer in Chippewa County, Michigan, during July through October of 1975 through 1990 (MDNR Wildlife Division, Data Files).

Year	Total number observed	Average no/100 hr observation time	Percent			
			Male	Female	Fawn	Unidentified
1975	202	6.11	7.9	34.2	27.7	30.2
1976	329	1.6	9.4	31.9	22.4	36.1
1977	332	9.9	11.1	34.0	18.6	36.1
1978	188	6.2	3.3	34.0	22.3	40.4
1979	102	3.1	7.8	39.2	24.5	28.4
1980	115	5.5	7.8	30.4	14.8	47.8
1981	187	5.6	13.4	39.0	24.1	23.5
1982	122	4.0	14.0	37.0	25.4	23.7
1983	176	5.8	10.8	39.8	21.6	27.8
1984	232	15.5	7.2	35.8	36.2	22.4
1985	137	15.7	6.6	43.1	29.2	21.2
1986	29	9.7	10.3	58.6	0.0	31.0
1987	69	26.0	14.5	27.5	23.2	34.8
1988	221	36.4	7.2	47.5	21.3	24.0
1989	358	120.9	4.7	33.8	29.9	31.6
1990	169	21.0	4.1	34.9	20.1	40.8

5.5.6 Commercial Fishing

5.5.6.1 Michigan

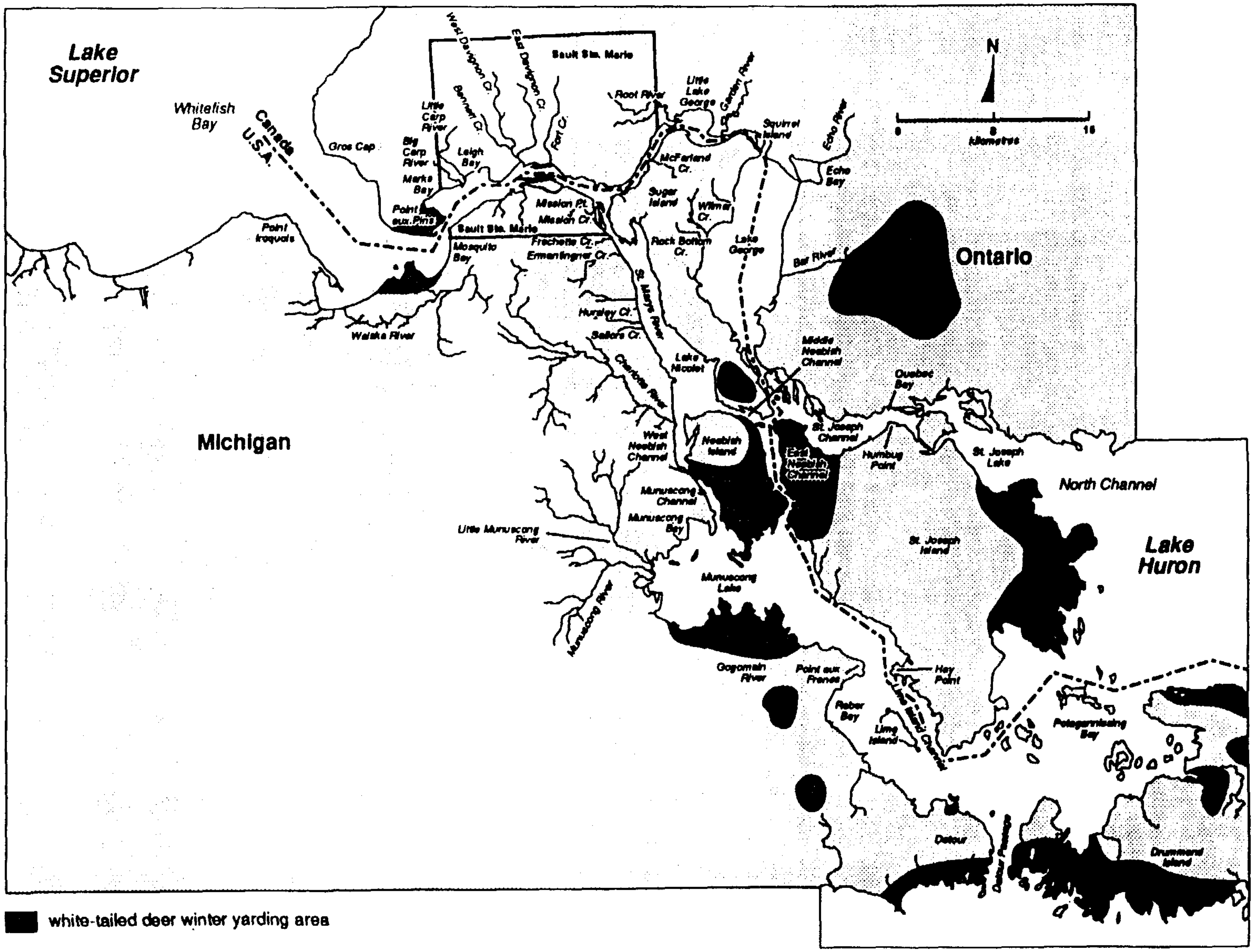
Commercial fishing by native people is ongoing only in the upper reach of the St. Marys River. Waters of Lake Superior, particularly Whitefish Bay, that have been designated for use by native peoples extend from Whitefish Bay into the upper reach of the St. Marys River (Figure 5.16). Tribal commercial fishing in this area is mostly for whitefish and lake trout. The 1988 whitefish harvest from the Michigan side of Whitefish Bay was 242,053 kg (Great Lakes Fishery Commission, 1990).

Figure 5.15

St. Marys River Remedial Action Plan

Distribution of white-tailed deer winter yarding areas on islands and on adjacent lands in the St. Marys River

(from Duffy et al. 1987)



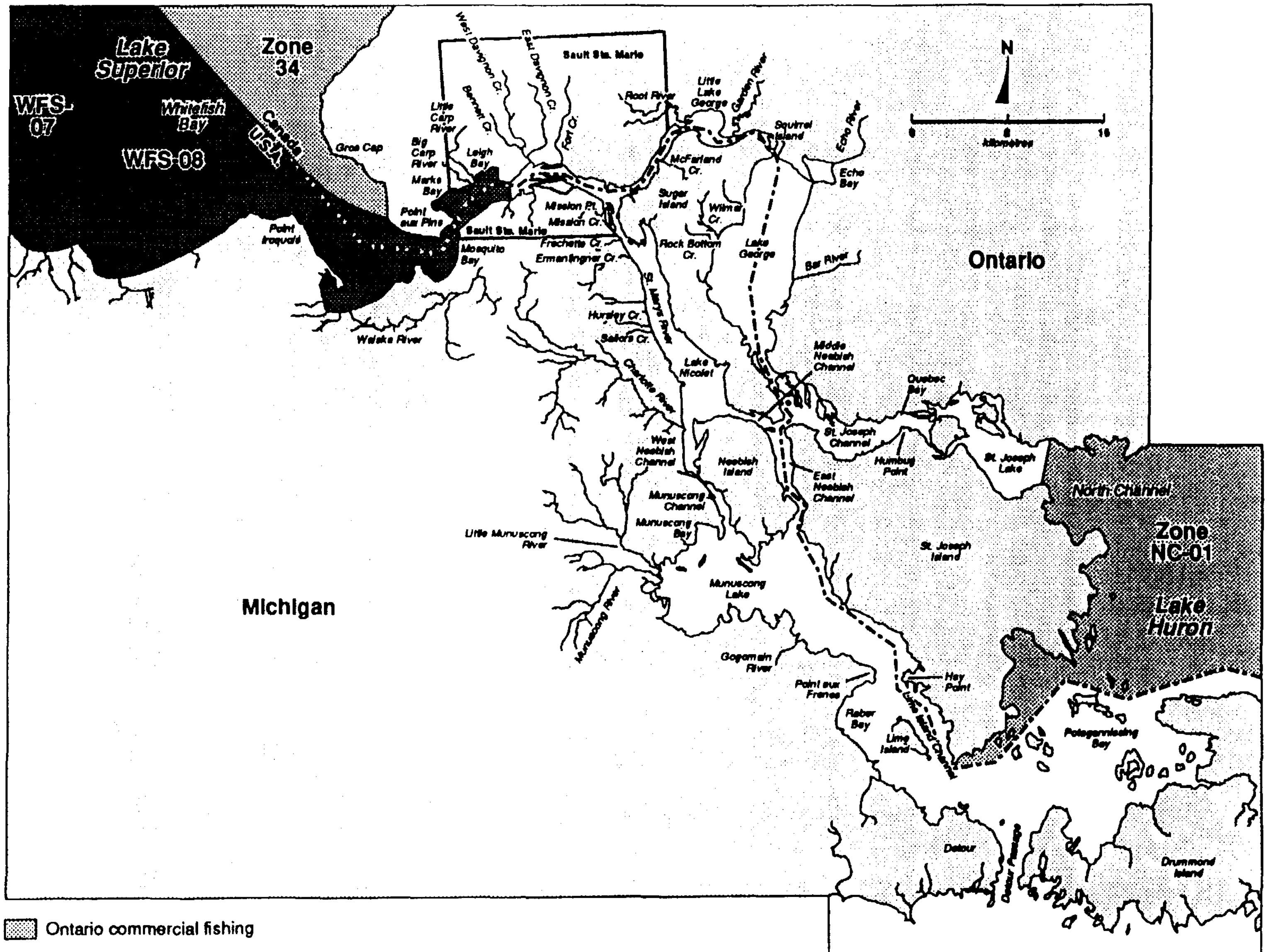
white-tailed deer winter yarding area

Figure 5.16

St. Marys River Remedial Action Plan

Location of commercial fishing management zones near and within the St. Marys River area of concern

(prepared from OMNR 1991 and MDNR Data Files)



Ontario commercial fishing

Native American commercial fishing

5.5.6.2 Ontario

Commercial fishing occurs in the waters of Lake Superior and Lake Huron in close proximity to the St. Marys River (Figure 5.16) however, the Ontario government prohibits commercial fishing, roughly from Point Louise in the upper river to Portlock Island, and the east side of St. Joseph Island (OMNR, 1983). Commercial fishing activities adjacent to the river are briefly summarized in the following paragraphs, since these operations potentially influence the river system's fisheries through shared fish stocks.

Seventeen commercial fishing licences for Lake Superior Management Zone 34 (Figure 5.16) have been issued by the OMNR, 13 of which have quotas for lake whitefish. The Batchawana Indian Band is purported to fish within Zone 34 however, the extent of this fishery is not known. Approximately 83% of the lake whitefish catch for this zone comes from the Gros Cap fishery in Whitefish Bay (B.A.R. Environmental 1988). The 1986 lake whitefish harvest from the Ontario portion of Whitefish Bay was 54,094 kg (Great Lakes Fishery Commission 1990). The lake whitefish stocks harvested in Whitefish Bay come from the spawning grounds located in the part of Whitefish Bay which is within the St. Marys River AOC (Figure 5.10).

The North Channel of Lake Huron has one commercial fishing zone, NC-01, which has its western limit near the east shore of St. Joseph Island. As of 1986, this area was fished regularly by one commercial fisherman. Also, it received occasional effort by six others (OMNR, 1987). Walleye and lake whitefish are the primary species sought within zone NC-01. The lake whitefish stocks harvested are not considered to be related to the St. Marys River stock, whereas it is suspected that walleye spawn either in the river or in its tributaries. The OMNR is currently attempting to confirm the origin of this stock.

Resource use conflicts include the unknown effects on lake whitefish of aggregate dredging in Whitefish Bay by A.B. McLean Ltd., and a perceived problem between sport fishermen and commercial fishermen concerning walleye stocks near the Seine Islands in the North Channel. Opposing fish management philosophies also exist between those dedicated to re-establishing self-sustaining stocks and those who wish to increase reliance on introduced species such as the Atlantic salmon.

5.5.7 Native Fishing

5.5.7.1 Michigan

The Chippewa-Ottawa Treaty Fishery Management Authority permits subsistence fishing in the St. Marys River. Subsistence fishing is defined as fishing for personal and family use, and not for sale. Treaty subsistence fishermen are allowed to use sport fishing gear including snagging gear, spears, gill nets which do not exceed 30.5 m in length, and other gear which are authorized by the tribes. Species taken include lake trout, lake whitefish, round whitefish, lake herring, walleye, yellow perch, sucker, burbot, northern pike, Atlantic salmon, Chinook salmon, catfish and smallmouth bass. A listing of recorded catches for 1981 to 1988 is provided in Table 5.10.

Although the tribal commercial fishery is restricted in its harvest of certain species, these restrictions do not apply to subsistence fishing in the St. Marys River.

Table 5.10 Subsistence harvest of fish from the St. Marys River, 1981 to 1988, as per the regulations of the Chippewa/Ottawa Treaty Fishery Management Authority (Inter-tribal Fisheries and Assessment Program, Data Files).

Species Taken	1981 (kg)	1982 (kg)	1983 (kg)	1984 (kg)	1986 (kg)	1987 (kg)	1988 (kg)
Lake trout	27.0	2.0	--	--	--	--	--
Lake whitefish	5.0	2.0	--	--	--	--	--
Menominee	0.5	24.0	--	--	7.0	--	9.0
Lake herring	--	--	--	--	--	--	--
Walleye	74.0	7.0	--	20.0	--	--	--
Yellow perch	57.0	7.0	3.0	1.0	0.5	2.0	17.0
Suckers	27.0	34.0	1.0	22.5	--	--	25.0
Burbot	0.5	--	--	--	--	--	--
Northern pike	178.0	6.0	4.5	9.0	--	--	33.0
Rainbow trout	20.0	--	--	--	--	--	2.0
Channel catfish	5.0	--	--	--	--	--	--
Smallmouth bass	12.0	--	--	--	--	--	--
Rock bass	--	1.0	--	2.0	--	--	--
Carp	--	--	--	2.0	--	14.0	--
Chinook salmon	--	14.0	--	--	--	--	--
Pink salmon	--	1.0	--	--	--	--	--
Bullhead	--	--	--	3.0	--	--	--
Other	--	--	--	--	4.0	3.0	28.0
Total	406.0	98.0	8.5	59.5	11.5	19.0	114.0

5.5.7.2 Ontario

Both the Garden River and Rankin Location Indian Reserves have subsistence fisheries.

In the 1930's, the Garden River Indian Band harvested considerable quantities of lake whitefish in the order of 9 tonnes annually. However, stock depletion in the lower St. Marys River redirected efforts toward other species. Former lake whitefish spawning and fishing areas near Pumpkin Point and Partridge Point are no longer considered to be productive waters for this species. Currently, the band's subsistence fishery is mainly walleye in the spring, although rainbow trout, yellow perch, northern pike, muskellunge and lake sturgeon are also taken. Pacific salmon are the species of interest in fall. Gill nets are used at the mouths of the Echo River, Garden River and Root River. The St. Marys River is generally avoided since the gear becomes badly fouled in the strong current.

Conflicts currently exist between the Batchawana Indian Band and the OMNR regarding aboriginal fishing rights, and a court case is pending.

5.5.8 Sport Fishing

Sport fishing is a major recreational activity in the St. Marys River, providing about 154,799 ($\pm$27,723) angler days annually (Rakoczy and Rogers 1988). Catch per unit effort (CUE) data for the river, exclusive of the rapids, declined from about 1.5 fish/angler-hour in the 1930's, to an average of about 0.5 fish/angler-hour through the 1970's (Figure 5.17) (Duffy *et al.*, 1987).

The OMNR has conducted about 20 creel surveys over the past 20 years in different areas of the river to assess changes in the sports fishery. Key findings were summarized by Krishka (1989) and are as follows:

- Upper St. Marys River: In the open-water season, angling has been directed at lake whitefish, yellow perch and northern pike, and more recently, brown trout. A winter ice fishery for lake whitefish exists in Marks Bay, Leigh Bay, and over the past few years, above the Canadian ship canal;

- St. Marys Rapids: A change has occurred in target species, from a rainbow trout/lake whitefish fishery prior to the 1980's, to that of a Pacific salmon fishery in the 1980's. Other species taken include rainbow trout, brook trout, brown trout, walleye, lake whitefish, and white sucker. A recent addition is the Atlantic salmon which is being stocked by the MDNR. Fishing quality has been relatively stable with a CUE of 0.1 fish/angler-hour when pink salmon are excluded from the creel (Table 5.11). Pink salmon first appeared in the harvest in 1977, with major runs now occurring in odd years. In 1985, the presence of this species resulted in a CUE of 0.45 fish/angler-hour (Table 5.11);

- Lower St. Marys River: An increased diversity of fish species supports a variety of angling opportunities which are lacking in both the rapids or upper river (Table 5.12). Northern pike, yellow perch, walleye, smallmouth bass, and panfishes are the sought after species. As well, brown bullhead, lake sturgeon, channel catfish, rainbow smelt and other less important gamefish are taken. Most of the fishing occurs during the ice-free seasons however, the Pine Island area provides ice fishing for yellow perch, walleye and northern pike from January to March. In 1988, a higher CUE of 0.60 fish/angler-hour, was measured in St. Joseph Channel, in comparison to the average CUE of 0.45 fish/angler-hour in the 1970's. Between 1979 and 1988, angler effort and estimated harvest increased four and six times respectively (Table 5.13). While northern pike was the preferred species during the 1970's, in 1988 this species was surpassed by yellow perch. Walleye remain a major component of the catch in this area. In Michigan waters, a lake herring fishery is largely confined to late June and July. In 1986, this fishery sustained an estimated 750,000 angler-hours of effort, and an estimated harvest of about 141,000 fish (MDNR, Data Files). During a two week period in July 1988, a creel survey along the south shore of St. Joseph Island in Ontario waters estimated 4,552 rod hours of activity, 3,171 lake herring harvested and a CUE of 0.70 fish/angler-hour (OMNR, Data Files); and

- St. Marys River tributaries: A spring rainbow trout fishery is associated with several tributaries including Big Carp River and Little Carp River. This was replaced by a fall fishery for coho and chinook salmon in these and other tributaries.

Figure 5.17

St. Marys River Remedial Action Plan

Average catch of fish in the St. Mary River, excluding the rapids, per angler per hour during 1937 to 1945 and 1971 to 1979

(from Duffy et al. 1987)

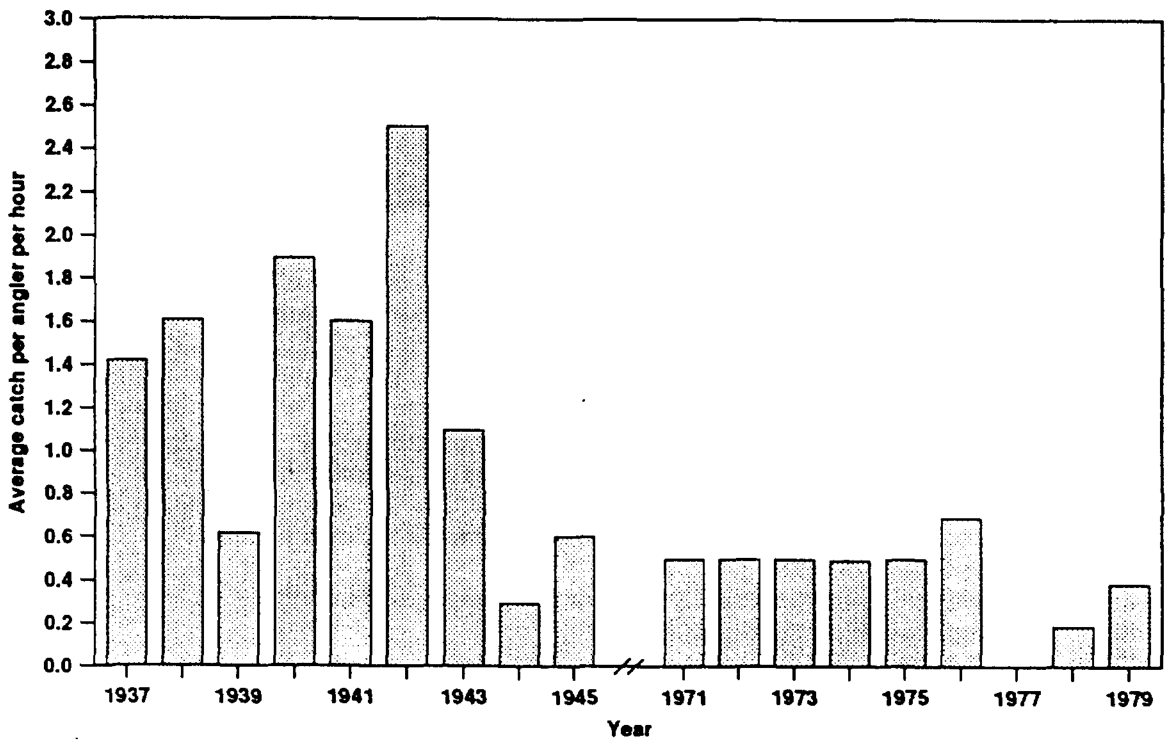


Table 5.11 Summary of creel results from the Ontario side of the St. Marys Rapids area of the St. Marys River (Wurm 1987 and OMNR Data Files).

	1972	1976	1977	1977	1982	1984	1985	1986
Months creeled	May-Aug	May-Aug	May-Aug	Aug-Nov	May-Sep	Aug-Jan	Mar-Oct	Aug-Nov
Period covered (days)	100	88	85	104	152	167	166	100
CUE (fish/rod-hr)	0.07	0.09	0.07	0.11	0.10	0.10	0.45	0.12
Effort (angler-hrs)	19971	10252	11391	3700	16818	15467	48303	26016
Harvest (fish kept)	1361	885	797	407	1740	1684	28724	3439

There are two estimates of the economic value of the St. Marys River sport fishery. Duffy *et al.* (1987) reported the fishery to be worth in the order of $2.5 million annually to Michigan anglers. Thibert (1985) anticipated that the St. Marys River and area fishery is worth between $15 and $20 million annually to Sault Ste. Marie, Ontario. Thibert (1985) also noted that:

- Anglers spend an estimated $500 per year on equipment;
- It costs about $26 per day (U.S. dollars) for an average fishing trip in 1983;
- Sault Ste. Marie, Ontario receives about $0.25 million in direct revenue from Michigan fisheries efforts;
- Sport fish generate about $25 to $40 of revenue per pound of fish caught to the local economy; and
- $1.00 invested in the sport fishing industry may return up to $200 to $300 in benefits.

According to Krishka (1989), St. Mary fish stocking programs have been carried out by various authorities along both sides of the border. The MDNR currently maintains stocking programs for atlantic salmon, chinook salmon, rainbow trout, brown trout, walleye and lake trout (Table 5.14).

No fish stocking of the St. Marys River is undertaken by the OMNR. However, Sault St. Marie, Ontario recently constructed a new fish hatchery along the city's waterfront. The hatchery was operational early in 1988, and produced 254,000 chinook salmon for stocking the St. Marys River and Lake Superior in the fall of that year. The Sault and District Anglers Association (SDAA) had been stocking the St. Marys River with chinook salmon prior to 1988. They continue to stock the river and Lake Superior with chinook salmon, brown trout and rainbow trout. Fish stocked by the SDAA in 1990 are as follows:

- Brown Trout: 21,820 at the Rapids; 17,010 in Lake Superior
- Chinook Salmon: 42,020 at the Rapids; 317,854 in Lake Superior
- Rainbow Trout: 21,344 at the Rapids; 24,948 in Lake Superior

5.5.9 Hunting and Trapping

Important waterfowl hunting areas include Pumpkin Point Marsh and Echo Bay on the east (Ontario) side of Lake George and Munuscong Lake (Michigan). During the 1979/1980 hunting season, hunters harvested about 1,100 migratory waterfowl in about 2,700 hours from Pumpkin Point Marsh (Duffy *et al.*, 1987). The

Table 5.12 Seasonal availability of selected game fish species within the three major sections of the Ontario waters of the St. Mary River (OMNR Creel Reports).

	Angling period	Comments
Upper River		
Brown trout	Apr-Nov	
Lake trout-splake	May-Jun	Gros Cap area
Rainbow trout	Apr-Dec	mainly in tributaries in Apr-May
Pink salmon	Aug-Nov	heavy spawning runs in odd years
Coho salmon	Apr-Jun	false run
Coho salmon	Sep-Nov	also at mouth and within tributaries
Chinook salmon	Apr-Jun	false run
Chinook salmon	Sep-Nov	also at mouth and within tributaries
Northern pike	Jun-Sep	
Lake whitefish	Apr-Dec	
Lake whitefish	Jan-Mar	ice fishing in Marks and Leigh Bays
Yellow perch	May-Oct	
St. Marys Rapids		
Brown trout	Apr-Nov	
Rainbow trout	Apr-Dec	spring spawning run
Chinook salmon	Apr-Jun	false run
Chinook salmon	Sep-Oct	spawning run
Coho salmon	Apr-Jun	false run
Coho salmon	Sep-Oct	spawning run
Pink salmon	Aug-Sep	fall spawning run in odd years
Atlantic salmon	Jan-Oct	good summer fishery
Walleye	Aug-Dec	night fishing recommended
Lake whitefish	Apr-Jun	
Lake sturgeon	Aug-Sep	
Lower River		
Brook trout	Apr-Sep	Rapids, Garden River, Root River
Brown trout	Apr-Nov	larger fish caught in fall
Rainbow trout	Apr-Dec	
Chinook salmon	Apr-Jun	false run
Chinook salmon	Aug-Oct	spawning run (below Rapids), also St. Joseph Ch. area
Coho salmon	Apr-Jun	false run
Coho salmon	Aug-Nov	spawning run (below Rapids), also St. Joseph Ch. area
Pink salmon	Aug-Sep	heavy spawning run in odd years
Lake sturgeon	Aug-Sep	below Rapids; mouth of Garden River
Lake whitefish	all year	not fished much in lower sections
Lake herring	Jun-Jul	south side of St. Joseph I.;N. Shore; St. Joseph Ch.
Walleye	May-Jun	mainly sections below Garden River
Walleye	Aug-Dec	mainly in area from Pine St. Marina to the Rapids
Yellow perch	Apr-Jun	
Yellow perch	Jan-Mar	winter ice fishing near Pine Island
Northern pike	Apr-Oct	
Northern pike	Jan-Mar	winter ice fishing near Pine Island
Smallmouth bass	Apr-Sep	St. Joseph Channel, Echo Bay, Munuscong Bay areas
Brown bullhead	Apr-Jun	mainly St. Joseph Channel, Bar River areas
Rainbow smelt	Apr-Jun	spawning run; St. Joseph Ch., East Shore of St. Joseph I.

Table 5.13 Summary of creel results from the St. Joseph Channel area in Ontario waters of the lower St. Marys River (Walker 1979 and OMNR Data Files).

	1974	1975	1976	1978	1979	1988
Months creeled	Jun-Sep	Jul-Aug	May-Aug	Jun-Aug	Jun-Aug	Jul-Sep
Period covered (days)	73	51	86	77	77	101
CUE (fish/rod-hr)	0.51	0.45	0.69	0.18	0.41	0.60
Effort (man-hrs)	10871	7293	4312	5155	10378	44249
Harvest (fish kept)	5544	3282	2975	912	4323	28420

average annual harvest of ducks in Chippewa County, Michigan, during 1961 to 1970 was 5214. Gamble (1989) listed the average annual 1976 to 1985 harvest of ducks as 5,636 for Chippewa County, which was the largest duck harvest among all the Upper Peninsula counties. Assuming that hunting success estimates for Chippewa County are similar to those in Ontario, roughly 12,700 hours were devoted to waterfowl hunting annually, with much of this probably concentrated along the St. Marys River (Duffy *et al.*, 1987). Mallard, ring-necked ducks and green-winged teal are the primary species taken early in the fall, with scaup, mallard and black ducks dominating the late October and November hunt (Duffy *et al.*, 1987 and Soulliere, MDNR, pers. comm.). Canada goose hunting throughout the fall has improved in recent years. Geese spending the night on the St. Marys River supply hunting opportunities 30 km inland on the Michigan side.

Riparian areas of the St. Marys River also support a number of big and small game animals and fur bearing mammals which are harvested by hunters and trappers. Duffy *et al.* (1987) reported that white-tailed deer and black bear are harvested on both sides of the river, while moose are taken on the Ontario side only. Harvested small game includes the ruffed grouse, snowshoe hare and woodcock (Table 5.15). Between 1935 and 1968, the increasing number of hunters increased the white-tailed deer harvest on Drummond Island. During the same period, the number of animals harvested was cyclical, with peaks occurring at five to ten year intervals however, since the early 1970's, both the numbers of hunters and animals harvested have declined and remained relatively stable (Duffy *et al.*, 1987). On St. Joseph Island, only 55 white-tailed deer were harvested by 525 hunters in 1978 (Duffy et. al. 1987). Since the introduction of the bucks only law in 1979, with limited doe permits allowed in recent years, the white-tailed deer population on St. Joseph Island has recovered to its highest numbers in 30 year. Local farmers/gardeners are suffering major property damage from deer browsing.

Beaver is the most commonly trapped species on both sides of the river, although mink, muskrat and river otter are also frequently taken. Marten, fisher and lynx are harvested in Ontario, but are currently protected in eastern Upper Michigan. Between 1981 and 1984, the total economic value derived from the harvest of furs taken from the Upper Peninsula of Michigan ranged between $4.5 and $8.6 million annually. Returns from trapping in 1984 in the Sault Ste. Marie district of Ontario approximated $100,000 (Duffy *et al.*, 1987).

Table 5.14 Fish stocking numbers for the St. Marys River, including both Canadian and U.S. waters, from 1985 through 1990 (OMNR and MDNR Data Files and City Hatchery Records (Ontario)).

Stocking Area	Species	Size‡	1985	1986	1987	1988	1989	1990
<u>Ontario (OMNR, SDAA*,SFDPA*)</u>								
Upper River	Rainbow trout	yr					1 011	1 250
	Chinook salmon	fg					44 205	17 557
St. Marys Rapids	Chinook salmon	fg	19 875	30 000	52 735	29 280	47 162	42 020
	Rainbow trout	yr					22 816	20 344
	Brown trout	yr						21 820
Lower River	Chinook salmon	fg	2 198			36 877		
	Rainbow trout	yr					1 027	1 000
<u>Michigan (MDNR)</u>								
Ashmum Bay	Brown trout	yr	13 500	15 000	15 000	15 000	15 000	14 999
	Walleye	ff	26 567	25 334		20 000	52 165	29 419
Aune Park	Lake trout	sf			2 000			
	Walleye	ff	29 982	25 334		20 651	46 671	56 721
	Atlantic salmon	yr			19 000	12 751	18 596	31 702
Rapids Area	Chinook salmon	sf	93 002	100 045	101 968	100 000	125 244	98 000
	Rainbow trout	yr	37 018	19 700	27 629		30 557	24 994
	Rainbow trout	ff	27 751			23 500	17 500	
	Rainbow trout	sf	2 148		7 000			
	Steelhead trout	yr	16 012	219 000	15 000	11 500	10 951	9 610
Waiska River	Walleye	ff		50 442		19 801		2 740
	Walleye	fry					525 000	472 500

Table 5.14 (Cont'd)

Stocking Area	Species	Size[‡]	1985	1986	1987	1988	1989	1990
Munuscong Bay	Walleye	ff						7 210
Potagannissing Bay	Walleye	ff		69 473	85 429	81 060	127 659	101 970
Detour Ferry Dock	Chinook salmon Lake trout	sf yr	50 000 50 000		80 300		57 228	
Detour Reef	Lake trout	yr					217 300	62 000
Drummond - Scammon	Lake trout Lake trout	yr ff	113 399	75 000	 187 566	173 400		138 650
Salt Point	Lake trout Lake trout	ff yr	 130 300	120 000	 40 000	150 000	150 000	
Birch Point	Lake trout	yr	35 000					
Black Creek	Lake trout	yr		78 100	65 500			
Whitefish Bay	Lake trout	yr		77 600				
Seymour Creek	Coho salmon Chinook salmon	sf	90 043 162 015	237 193 100 045	219 956 250 276			
Whitefish Bay	Lake trout	ff						150 000

[*]Sault and District Anglers Association
[†]Sport Fish Development Program
[‡]yr = yearlings, fg = fingerling, sf = spring fingerling (released before July 1), ff = fall fingerling (released after July 1), fry = newly hatched.

Table 5.15 Small game hunting statistics (5-year average for 1985-1989) for Chippewa County, Michigan (MDNR, Wildlife Division Surveys Section, Data Files).

Species	Hunters	Days Hunted	Harvest
Ruffed grouse	3,600	25,600	18,000
Woodcock	1,600	10,900	8,900
Snowshoe hare	2,100	10,400	8,800
Cottontail rabbit	300	3,400	700
Squirrels	600	3,700	2,200

5.5.10 Recreational Boating/Marinas

The St. Marys River is used for power boating, sailing, yachting, houseboating, etc., by local and transient boaters. As well, boat rentals and fishing charters are available.

Currently, there are nine marinas between Bruce Mines and Sault Ste. Marie, providing many of the supplies and services such as gas, boat launching, parking, mooring, repairs, food, restrooms and sewage pump out facilities that are required by pleasure craft (Table 5.16). Expanded marina facilities under construction at Richards Landing and Hilton Beach on St. Joseph Island, will provide support facilities for large and small pleasure craft which use the waterway. Sault Ste. Marie, Ontario is developing its waterfront by constructing a marina at the Norgoma marine park area and recommendations have been made to the city for improving facilities and navigational aids along the St. Marys River (Table 5.17).

5.5.11 Other Recreational Uses

There are a number of other summer and winter recreational uses which are provided by the St. Mary River however, very little is known about their extent and economics. Such uses include water skiing, windsurfing, skating, cross-county skiing, snowmobiling, hiking, picnicking and nature appreciation. In Michigan there are two public beaches, the Sherman Park Beach is located at the head of the St. Marys River and is upstream of all discharges. The Sugar Island Township Park beach is located on the northwest shore of Sugar Island near where the river splits into the Lake George Channel and Lake Nicolet.

In Ontario there are no areas designated as 'public beaches' there are several general areas along the river where water recreation commonly occurs (Figure 5.18.). Recreational activities also occur along the Michigan shore where there are no beaches.

Table 5.16 Marina operations and facilities along Ontario waters of the St. Marys River (Krishka 1989).

Operation	Location	Boat Launch	Docking Facilities	Services	Support Facilities
Bruce Mines Marina	Bruce Mines	x	x	x	x
Desbarats Marina	Desbarats			x	x
Hilton Beach Marina	Hilton Beach	x	x	x	x
Holder Marine	Desbarats	x	x	x	
Holiday Inn Docks	Sault Ste. Marie		x	x	x
Kensington Point	Bruce Mines/Desbarats		x		
Norgoma Marina	Sault Ste. Marie		x		
Pine Street Marina	Sault Ste. Marie		x	x	x
Richard Landing Marina	Richards Landing	x	x	x	x

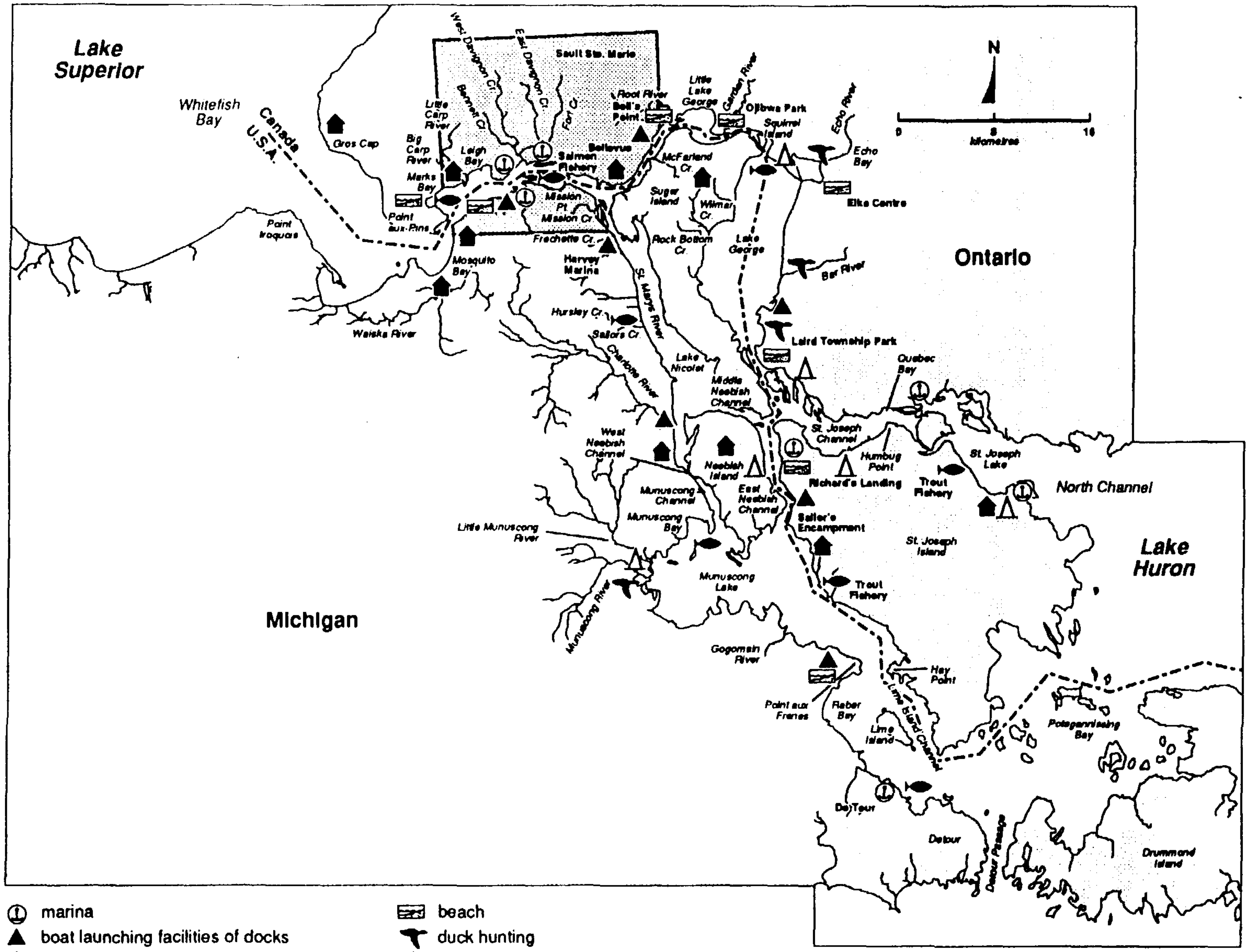
Table 5.17 Recommended aids to navigation and facility improvements within St. Marys River waterway from Sault Ste. Marie to Bruce Mills as of 1985 (Krishka 1989).

Area	Recommendations
Sault Ste. Marie	• add downtown marina facilities, with transient slips • establish a full range of marina services (repair, parts, lift-out, etc.) • provide a boater's guide to Sault Ste. Marie boaters and tourist services • add electricity and showers at Holiday Inn, Algo Club and Pine Street marinas • provide shuttle service from marinas to the Queen Street shopping area • add gas and diesel pumps at the Algo Club or Holiday Inn docks (or at a new downtown marina) • expanded chart of Sault Ste. Marie, in particular showing the approach to the Pine Street marina, or alternatively, preparation of a brochure with an expanded chart-sketch
Sault Ste. Marie to Hilton Beach	• a lighted "fairway" marker at the end of the Channel on Lake George • expanded and updated chart of the St. Joseph Channel covering the area from East Neebish Island to Hilton Beach area • chart small craft routes and identify them on the charts
Richards Landing	• seasonal slips and showers
Hilton Beach	• add 30-40 more slips
Bruce Mines	• showers • convenience stores

Figure 5.18

St. Marys River Remedial Action Plan

Location of the most commonly used water recreational areas in the St. Marys River



marina
boat launching facilities of docks
cottages
areas of interest to sport fishing
beach
duck hunting
campgrounds

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have been accomplished upstream of Liston's sampling points by diatoms in the plankton of Whitefish Bay, or by benthic and littoral communities in reaches of the river.

6.1.1.11 Chlorophyll *a*

Chlorophyll *a*, the main photosynthetic pigment in plants and algae, is an indicator of biomass at the time of sampling. Concentrations are influenced by the combined physical, chemical, and biological factors in an aquatic environment and therefore, are an integrative index reflecting algal and plant standing stocks. An average concentration of 0.88 μg/L for the St. Marys River (Table 6.1) is very low, falling within the range of 0.3 μg/L to 3.0 μg/L which is typical of oligotrophic waters (Wetzel, 1983).

6.1.1.12 Aesthetics

Floating scum is periodically reported along the north shore of Sugar Island in Michigan. In Ontario, mats of oily fibrous material mixed with wood chips/fibre occasionally occur between Sault Ste. Marie and the Lake George Channel. The degree of this problem is not known. As well, oil slicks appear from time to time downstream from the Algoma Slip and Terminal Basin. Since March 1990, no complaints of floating oil have been received. This may be a result of improvements made at Algoma Steel and that Algoma was on strike from July 31, 1990 to April, 1991 (G. LaHaye, OMOE, pers. comm.).

6.1.2 Water Quality - Contaminants

6.1.2.1 Background

Water quality surveys of the St. Marys River in 1947 and 1948 found unacceptable concentrations of phenols (IJC 1951). Other surveys (Veal 1968, Hamdy *et al*., 1978 and OMOE Data Files) indicated elevated concentrations of phenols, iron, cyanide, ammonia, zinc and sulphide in surface waters downstream of Ontario industrial and municipal sources.

As part of the UGLCCS (1988), OMOE sampled a series of transects across the St. Marys River between Leigh Bay and the Lake George Channel and Lake Nicolet. Transect locations are shown in Figure 6.1 and are numbered by their distance in statute miles upstream (prefix SMU) and downstream (prefix SMD) of the St. Marys Rapids. Sampling was undertaken in 1986 and 1987 at several locations along each transect between the Michigan and Ontario shores. Samples were analyzed for phenols, cyanide, ammonia, phosphorus, iron, zinc and polycyclic aromatic hydrocarbons (PAHs). Results from this study are presented in the following sections dealing with transboundary transport and downstream water quality conditions.

U.S. and Canadian waters of the St. Marys River do not mix to a significant extent in the upper river or main channel. Transboundary pollution of phenols, ammonia, cyanide, iron and zinc does not occur upstream of transect SMD 2.6 however, some cross-channel mixing is evident at SMD 2.6. Although concentrations of iron, zinc, cyanide and ammonia did not exceed PWQO, Michigan WQS or GLWQA objectives in Michigan waters at this location, the mean phenol concentration slightly exceeded the GLWQA objective of 0.001 mg/L in Michigan waters (Figure 6.2). The physical configuration of the channel at the head of the Lake George Channel and the division of flow around Sugar Island creates a zone of high water velocity towards the Sugar Island shoreline (Hamdy *et al*., 1978). In the Lake George Channel, secondary currents and decreased velocities enhance cross-channel mixing. As a result, contaminant inputs from upstream discharges that were confined to the Ontario shoreline of the river can contribute to trans-boundary contamination along the Sugar Island shoreline.

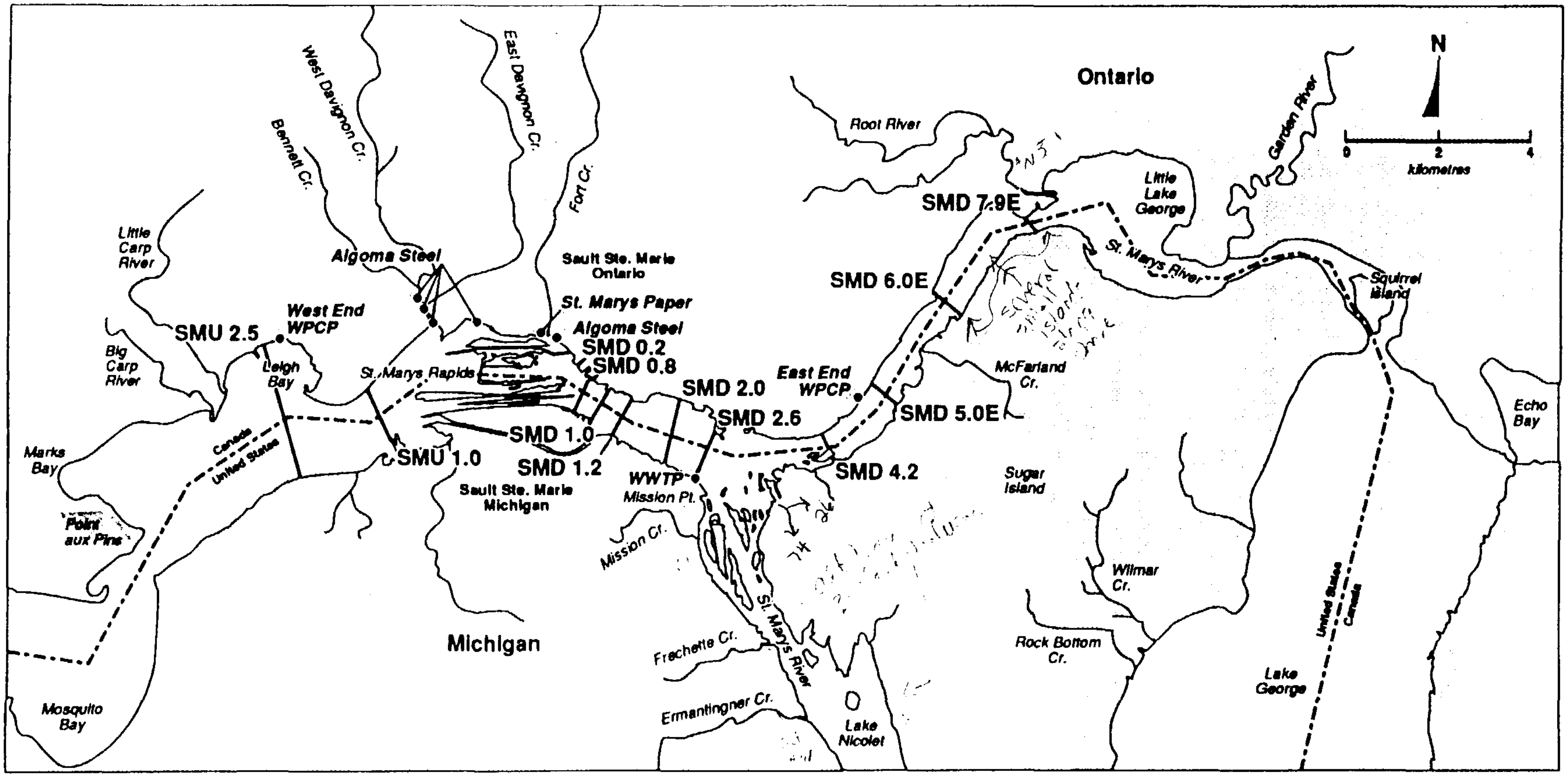
As discussed below, water quality monitoring results indicate that concentrations of phenols, ammonia and cyanide have declined steadily along the Ontario shoreline between 1969 and 1980 (Kauss 1986). By 1986,

Figure 6.1

St. Marys River Remedial Action Plan

Major point source dischargers and Ontario Ministry of the Environment (OMOE) sampling transects in 1986 and 1987

(from UGLCCS 1988)



• point source discharge location

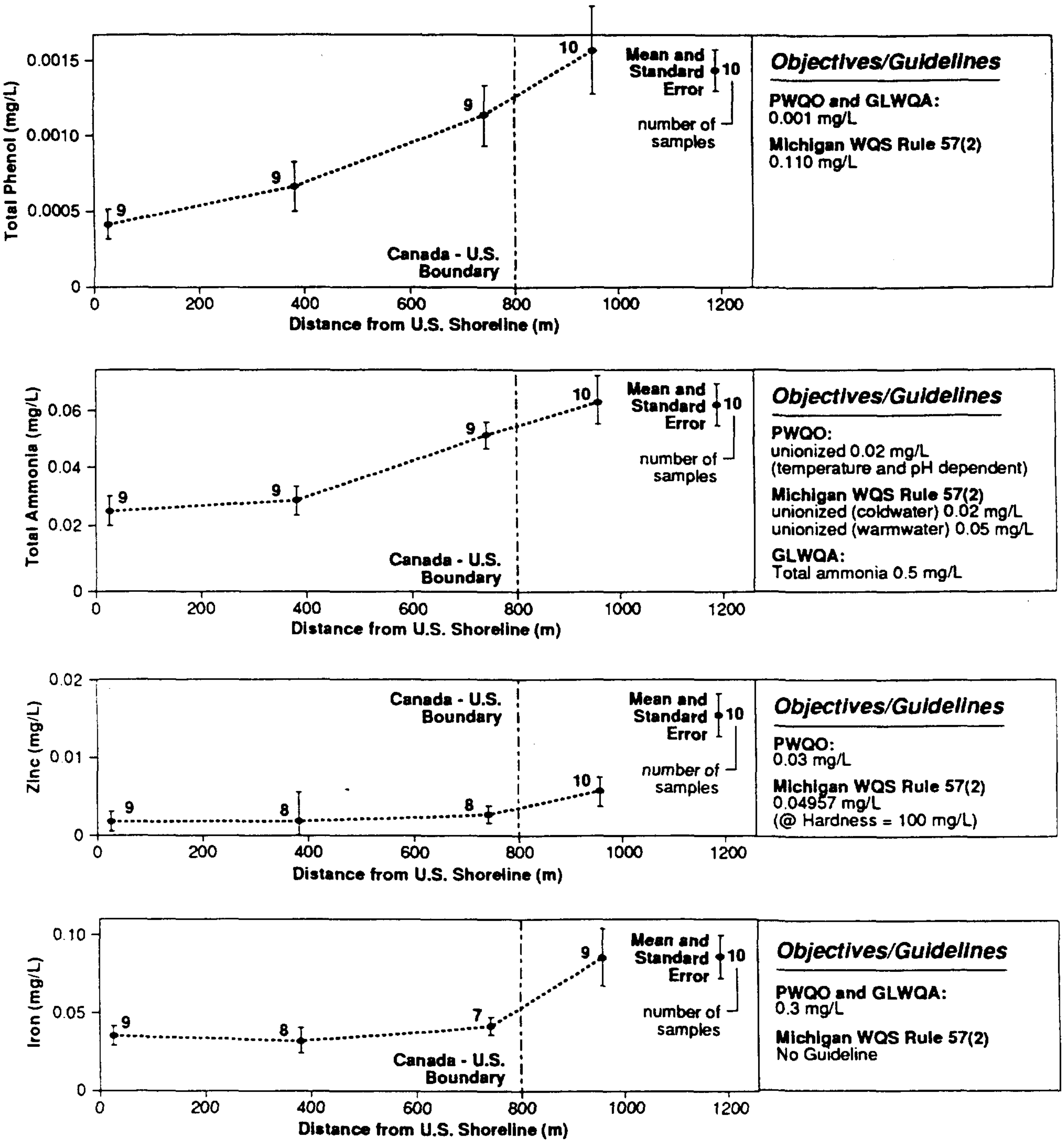
— sampling transect

Figure 6.2

St. Marys River Remedial Action Plan

Distribution of contaminants across the St. Marys River at transect SMD 2.6 during the 1986 and 1987 OMOE surveys

(from UGLCCS 1988)



concentrations of these parameters were approaching OMOE objectives for the protection of aquatic life. The improvements are attributable to reductions in: the loadings of phenols, ammonia-nitrogen and free cyanide from Algoma Steel; suspended solids from St. Marys Paper; and phosphorus and settleable organic matter from local WPCPs. Also, the redevelopment of the Great Lakes Power Corp. hydroelectric facility in 1982 (now the Clerque Generating Station) resulted in an increase in flow along the Ontario shoreline from 21% of the river's total flow to over 40%, thereby diluting contaminant concentrations.

6.1.2.2 Total Phenols

Total phenol concentrations have shown an historical downward trend downstream of Algoma Steel discharges (Figure 6.3). For example, mean concentrations 300 m downstream from the Algoma Terminal Basins outfall (at SMD 0.2) declined from 0.050 mg/L in 1973 to 0.015 mg/L in 1980, to 0.0012 mg/L in 1986. Similar trends and exceedences were observed at transects SMD 1.2 and SMD 2.0, 1,500 and 3,000 m respectively downstream of the discharge (Figure 6.3). At transect SMD 2.0, mean annual total phenol levels ranged from 0.019 to 0.003 mg/L between 1970 and 1980. In 1986, total phenol concentrations exceeded the Ontario PWQO and the GLWQA specific objective of 0.001 mg/L, 300 metres downstream from the Algoma Terminal Basins outfall (0.0012 mg/L). All stations as far downstream as 4 km (station SMD 2.6) had levels of total phenols exceeding the PWQO and the GLWQA guideline (Figure 6.2). Mean phenol concentrations in waters close to the Ontario shore were 0.0016 mg/L. U.S. waters at station SMD 2.6 also contained levels of total phenols with a mean concentration of 0.0012 mg/L indicating transboundary contamination (Figure 6.2). Total phenol concentrations still exceeded the PWQO and GLWQA objective in the Algoma Steel Slip (0.0036 mg/L) and at the mouth of the Slip (0.0034 mg/L).

In 1986 and 1987, average total phenol concentrations in water samples collected along the Michigan shoreline were below the 0.001 mg/L objective.

The Michigan WQS (January 1991), Rule 57(2) guideline for total phenols is 0.110 mg/L. This guideline was not exceeded in any water sample downstream of the Terminal Basins outfall. The highest value, 0.072 mg/L occurred 300 m downstream of this outfall in 1976. Ambient water samples, collected as early as 1948, did not exceed the Michigan WQS for total phenols (UGLCCS 1988).

6.1.2.3 Ammonia

Total ammonia concentrations have shown significant declines along the Ontario shore (Figure 6.4). Total ammonia concentrations 300 m downstream of the Terminal Basins outfall have decreased from approximately 0.6 mg/L in 1974 to <0.05 mg/L in 1986 (Figure 6.4) (UGLCCS 1988). In 1986, total ammonia concentrations increased slightly downstream of the East End WPCP at transect SMD 5.0E. This increase was considered to be localized. Concentrations at the Lake George Channel outlet were similar to those observed at the inlet (0.046 mg/L) (UGLCCS 1988).

The GLWQA objective for total ammonia is 0.5 mg/L. This objective was exceeded in 1974 water samples 300 m downstream of the Terminal Basins outfall. Subsequent samples, taken during and after 1980, did not exceed this objective. Both the PWQO and Michigan WQS Rule 57(2) guidelines are for unionized ammonia. The PWQO for unionized ammonia is 0.02 mg/L with the amount of unionized ammonia is dependent upon water temperature and pH. The Michigan WQS for unionized ammonia is 0.02 mg/L in coldwater and 0.05 mg/L in warmwater. In 1986, calculated unionized ammonia concentrations did not exceed the PWQO or the Michigan WQS for unionized ammonia.

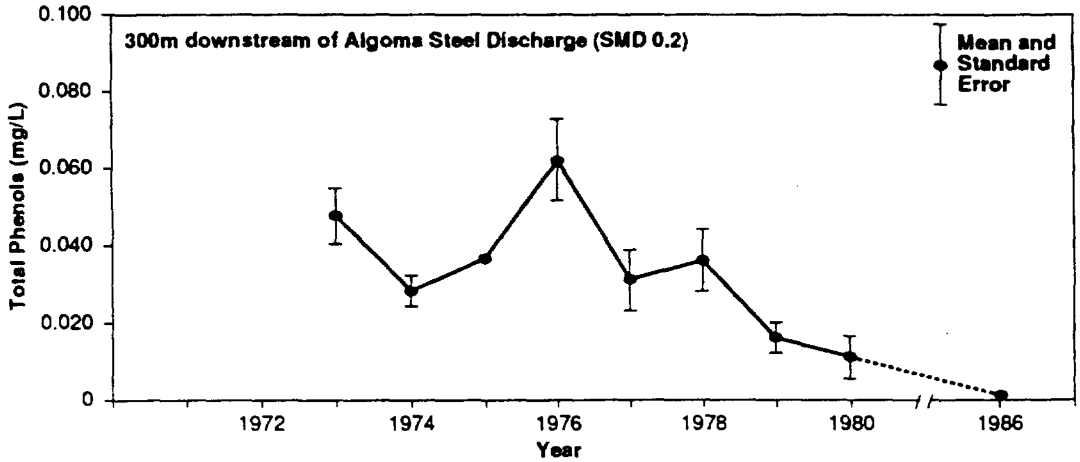
1989 water quality monitoring was conducted downstream of the East End WPCP following its upgrade. Four samples collected during August, 1989, ranged from 1.47 to 2.85 mg/L total ammonia (P. Kauss, OMOE, pers. comm.) all of which exceeded the GLWQA objective of 0.5 mg/L for total ammonia. Unionized ammonia concentrations calculated for these samples, using temperature and pH measuments,

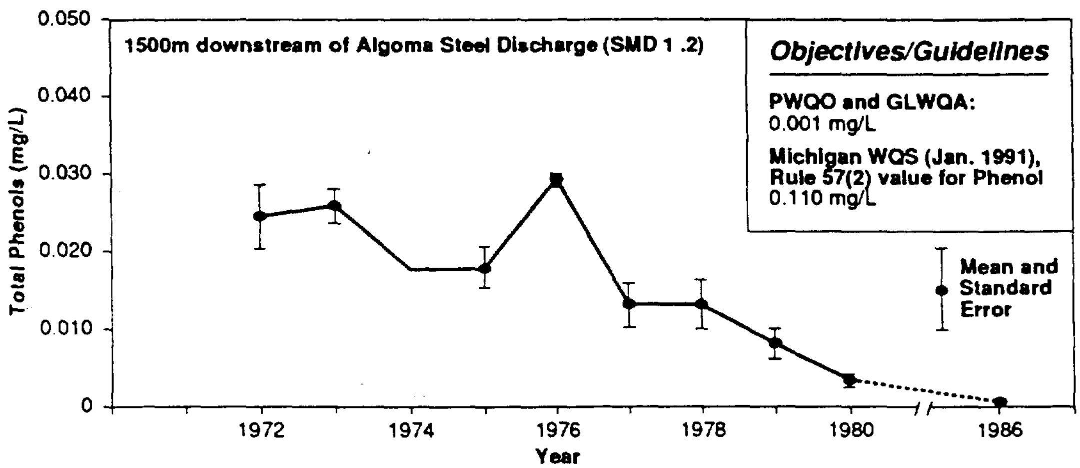
Figure 6.3

St. Marys River Remedial Action Plan

Temporal trend of total phenols concentrations in the St. Marys River at various distances downstream of the Algoma Steel discharge along the Ontario shore line

(from UGLCCS 1988)





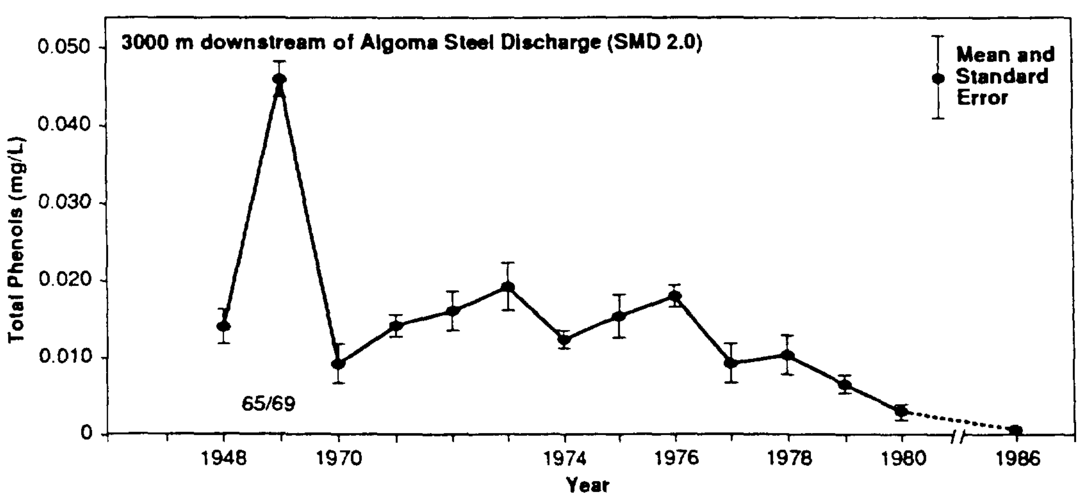
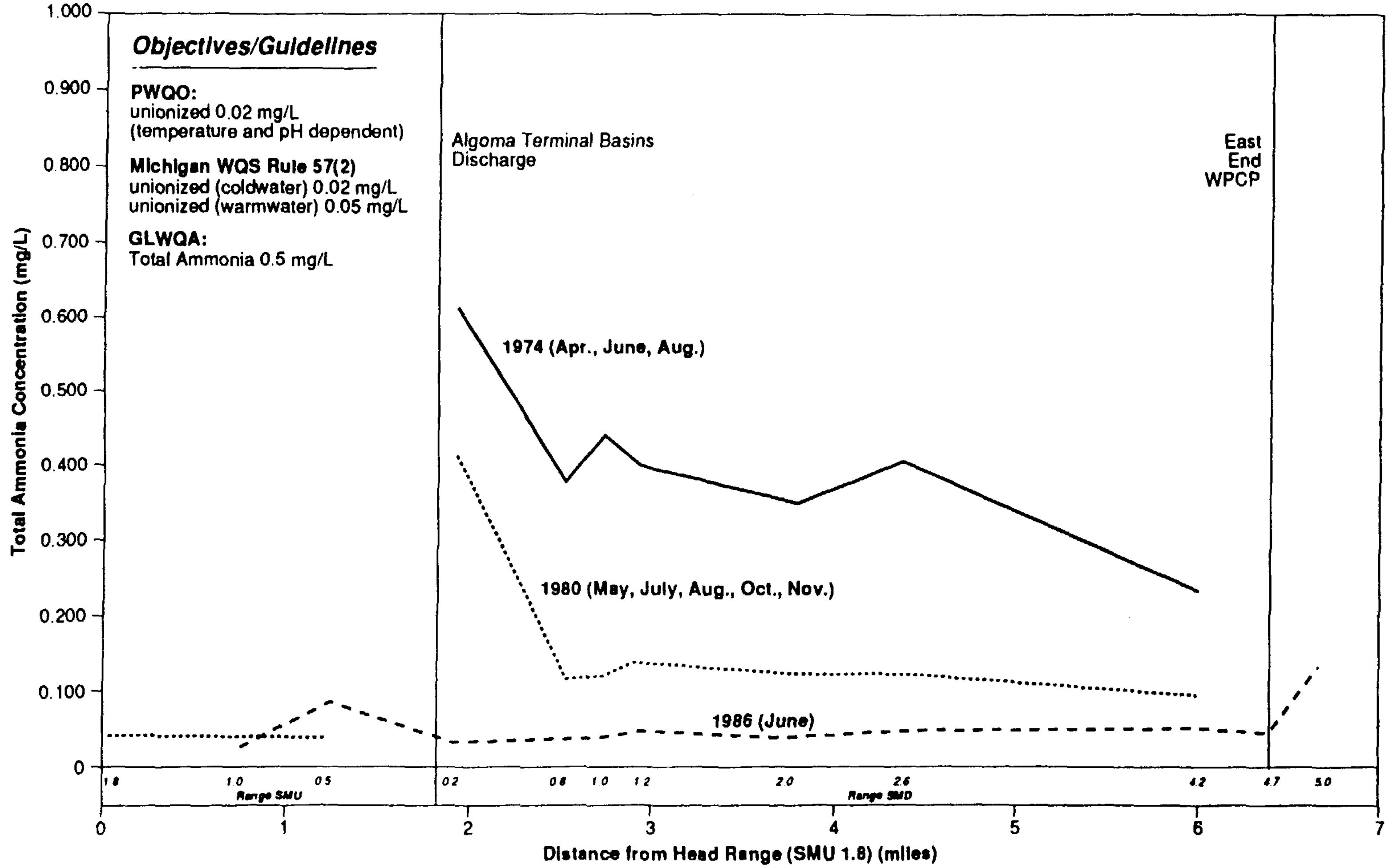


Figure 6.4

St. Marys River Remedial Action Plan

Ammonia (total, unfiltered) distribution and yearly trends along the Ontario shore

(from UGLCCS 1988)



yielded values ranging from 0.020 to 0.046 mg/L (P. Kauss, OMOE, pers. comm). Unionized ammonia concentrations in all four samples exceeded the PWQO and MWQS (coldwater) of 0.02 mg/L.

6.1.2.4 Cyanide

Free cyanide peaks occurred 300 m downstream from the Algoma Steel Terminal Basins discharge in 1974 and 1980 with mean concentrations of 0.3 and 0.06 mg/L respectively. More uniform levels occurred downstream. In 1974 mean free cyanide concentrations ranged from 0.054 to 0.07 mg/L downstream along the Ontario shore up to 6 km downstream of the Algoma discharge (Figure 6.5). Mean 1980 free cyanide values ranged from 0.01 to 0.02 mg/L between 1000 and 3000 metres downstream of the Algoma discharge (Figure 6.5). All 1974 and 1980 mean free cyanide concentrations exceeded the PWQO of 0.005 mg/L, Michigan's Rule 57(2) Guideline (January 1991) of 0.004 mg/L and the U.S. EPA chronic Ambient Water Quality Criteria (AWQC) of 0.0052 mg/L.

Free cyanide concentrations were considerably lower in 1986, both upstream and downstream from Algoma's Terminal Basins discharge with a uniform, mean concentration of approximately 0.0025 mg/L (Figure 6.5). 1986 free cyanide levels did not exceed the PWQO, Michigan's Rule 57(2) Guideline (January 1991) or the U.S. EPA chronic Ambient Water Quality Criteria (AWQC).

6.1.2.5 Iron

Iron concentrations ranged between 0.018 mg/L and 0.690 mg/L in 1986-1987. No distinct longitudinal (upstream-downstream) variations were noted (UGLCCS 1988). Immediately downstream of the Terminal Basins outfall, (SMD 0.2), the mean concentration was 0.060 mg/L, with a maximum of 0.69 mg/L. In the Algoma Slip, iron exceeded the PWQO and GLWQA specific objective of 0.3 mg/L (average of 0.445 mg/L, with a maximum of 1.0 mg/L). All samples met the U.S. EPA AWQC of 1 mg/L for chronic toxicity. There is no Michigan WQS for iron.

Iron levels along the Michigan shoreline in 1986 and 1987 ranged between 0.008 mg/L and 0.087 mg/L.

6.1.2.6 Zinc

Zinc concentrations along the Ontario and Michigan shoreline in 1986 and 1987 showed no distinctive longitudinal variations. Concentrations ranged between 0.001 mg/L and 0.009 mg/L, a decrease from 1980 when concentrations of 0.01 mg/L were prevalent. All 1986 and 1987 concentrations were below relevant water quality standards or guidelines (UGLCCS 1988).

6.1.2.7 Phosphorus

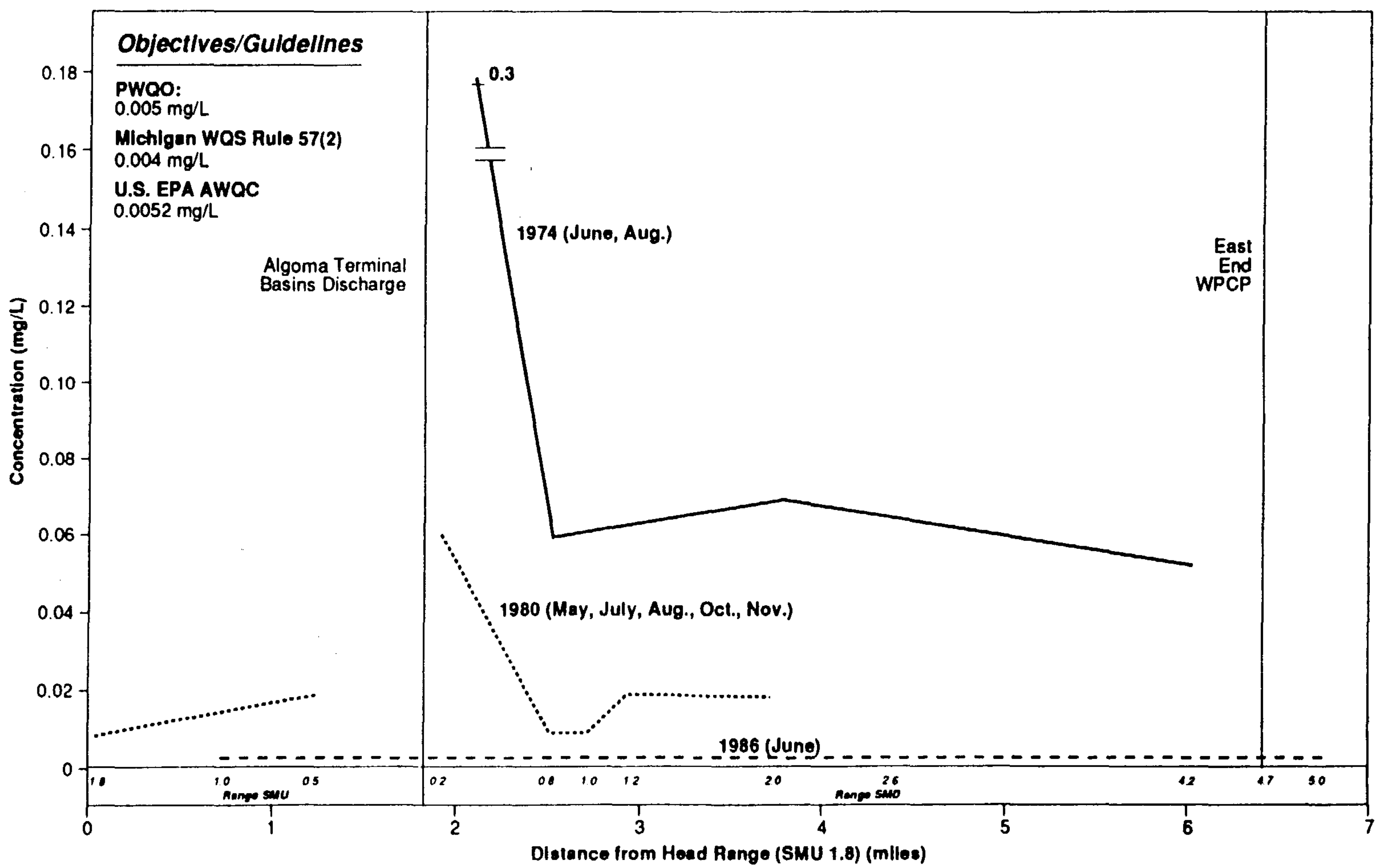
Phosphorus levels ranged between 0.002 mg/L and 0.051 mg/L along the Ontario shoreline and 0.005 mg/L and 0.014 mg/L along the Michigan shore in 1986 and 1987 (UGLCCS 1988). The highest level (0.051 mg/L) occurred immediately downstream of the East End WPCP at SMD 5.0E. No elevated concentrations (relative to upstream levels) were noted downstream of the Sault Ste. Marie, Michigan WWTP. In 1986 and 1987, phosphorus levels exceeded the Ontario PWQO of 0.030 mg/L downstream of the East End WPCP. This objective was still occasionally exceeded immediately downstream of the outfall during 1989 surveys conducted by OMOE following upgrading of the plant (OMOE, unpublished data). In addition, excessive amounts of algae observed in embayments and other slow-moving areas of the river suggest that phosphorus levels in these areas exceed the PWQO. During the summer of 1990, OMOE received a number of complaints regarding floating algae on the river below the East End WPCP.

Figure 6.5

St. Marys River Remedial Action Plan

Free Cyanide (total, unfiltered) distribution and yearly trends along the Ontario shore

(from UGLCCS 1988)



6.1.2.8 Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) have been frequently reported from the St. Marys River in recent years. The only current criterion is the U.S. EPA proposed a criterion of 31 ng/L for total PAHs. This reflects "maximum protection of human health from the potential carcinogenic effects of PAHs due to ingestion of contaminated aquatic organisms which may result in an incremental increase of cancer risk of 1 in 1,000,000 over a 70 year lifetime" (UGLCCS 1988).

In 1985, large volume sampling was undertaken to determine PAHs associated with the aqueous phase of St. Marys River waters (Figure 6.6 and Appendix 6.1 (Table 6APP.1)). PAHs in the particulate and whole water phases were not determined in the 1985 survey. Concentrations of total PAHs in samples taken from Leigh Bay (Station 3) and off the Algoma Slag Site (Station 4) were similar to the upstream background level of 3.99 ng/L (Station 2). Concentrations increased downstream, reaching a peak of 31.8 ng/L in the Algoma Slip (Station 7). Benzo(a)anthracene, which was absent in the upstream samples, was found at levels of 0.23 ng/L at Station 7 and 0.38 ng/L at Station 5. Elevated total PAHs, relative to the upstream site, persisted downstream (Station 10) at least 1 km from the Terminal Basins discharge. The PAH levels along the Michigan shore (3.2 ng/L-3.6 ng/L) were similar to the background concentration (4.0 ng/L) indicating no transboundary pollution (UGLCCS 1988).

In 1986, the concentration of PAHs associated with suspended particulate matter, the aqueous phase and whole water, were determined using a centrifuge sampling technique (UGLCCS 1988). It should be noted that "aqueous phase" is operationally defined by the sampling technique used, and may include organic material or colloids (i.e. humic acids) not removed by the centrifuge. Twelve stations between Leigh Bay and the Sault Ste. Marie East End WPCP were sampled. Sample locations and a summary of total PAHs is shown in Figure 6.7. Total PAHs and benzo(a)pyrene concentrations are summarized in Table 6.3. (Refer to Appendix 6.1: Tables 6APP.2, 6APP.3 and 6APP.4 for individual PAHs). Results from this survey are as follows:

- Upstream stations 1 and 2, showed only trace amounts of total PAHs on suspended particulates, suggesting that PAHs occurred only in the aqueous phase at these stations in 1985 (Figure 6.7 and Table 6.3).

- At Station 4, in the vicinity of the Algoma Slag Site, total PAHs associated with suspended particulates were 12,046 ng/g at 1.5 m below surface and 1,412 ng/g at 0.5 m off bottom (Figure 6.7 and Table 6.3). These concentrations corresponded to aqueous phase levels of 26.57 ng/L and 9.49 ng/L, respectively (Table 6.3), resulting in estimated combined (whole water) concentrations of 39.81 ng/L and 11.04 ng/L, respectively (Table 6.3). The former is above the U. S. EPA criterion of 31 ng/L total PAHs for the protection of aquatic organisms.

- Benzo(a)pyrene was detected at stations 4, 6, 8, 9, 11 and 12 all of which are downstream of the Algoma Slag Site (Figure 6.7 and Table 6.3). Levels of benzo(a)pyrene in whole water at these stations ranged from 0.29 ng/L to 140.96 ng/L.

- The total PAH concentration associated with the suspended particulate phase in a near-bottom sample at Station 6 in the Algoma Slip (in the vicinity of the 76 cm (30 inch) and 152 cm (60 inch) blast furnace sewer outfalls, and downstream of East Davignon and Bennett Creeks) was 55,686 ng/g (Figure 6.7 and Table 6.3). This corresponded to a whole water total PAH concentration of almost 3,900 ng/L, which greatly exceeds the above U.S. EPA guideline of 31 ng/L. As well, concentrations of the 16 individual PAH compounds in whole

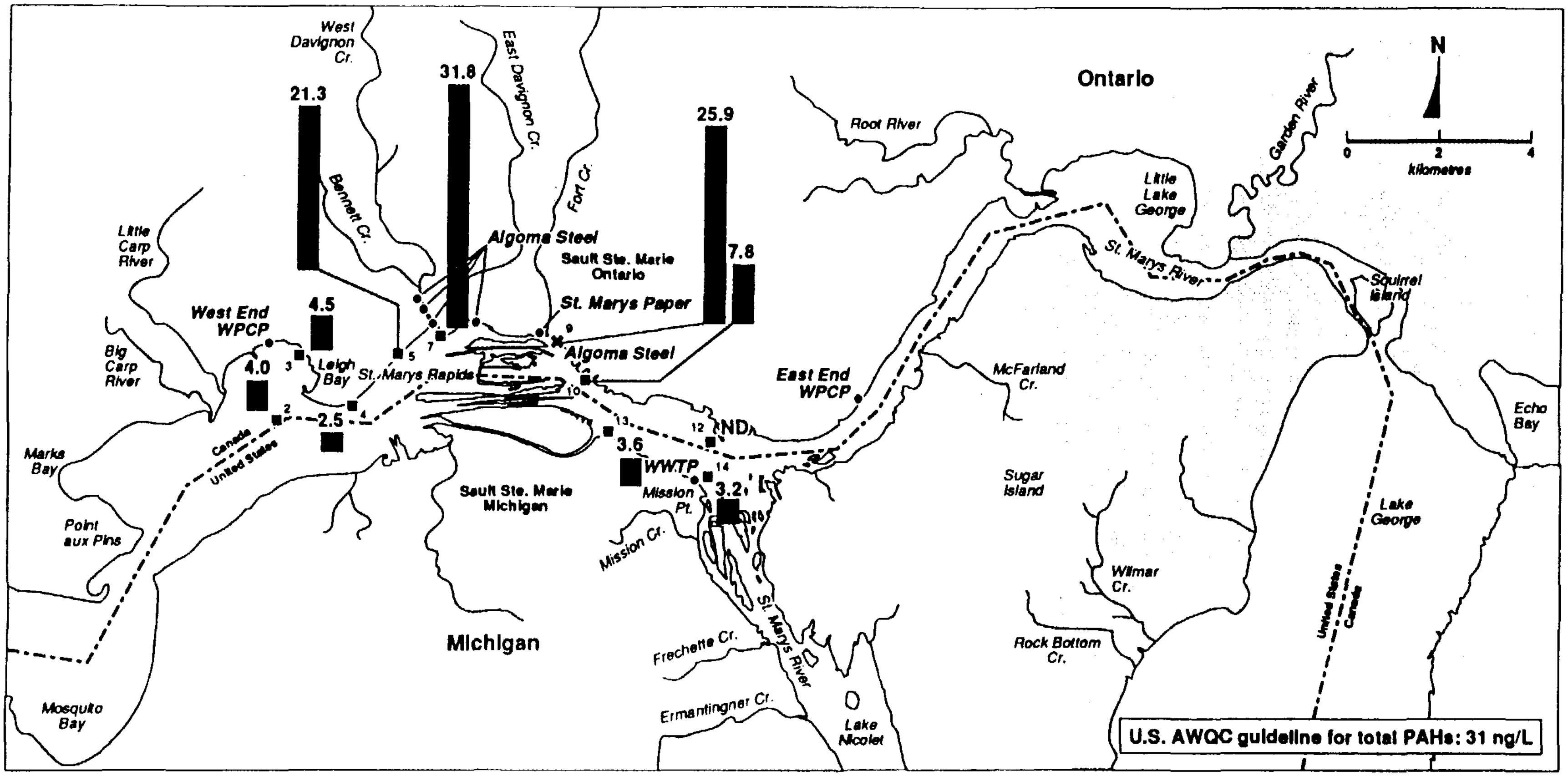
Figure 6.6

St. Marys River Remedial Action Plan

Total polycyclic aromatic hydrocarbons (PAHs) (ng/L) associated with the aqueous phase of St. Marys River water, 1985

See Appendix 6.1, Table 6 APP.1 for data

(from UGLCCS 1988)



✖ sampling and point source discharge location

• point source discharge location

■ sampling location

ND Not Detected

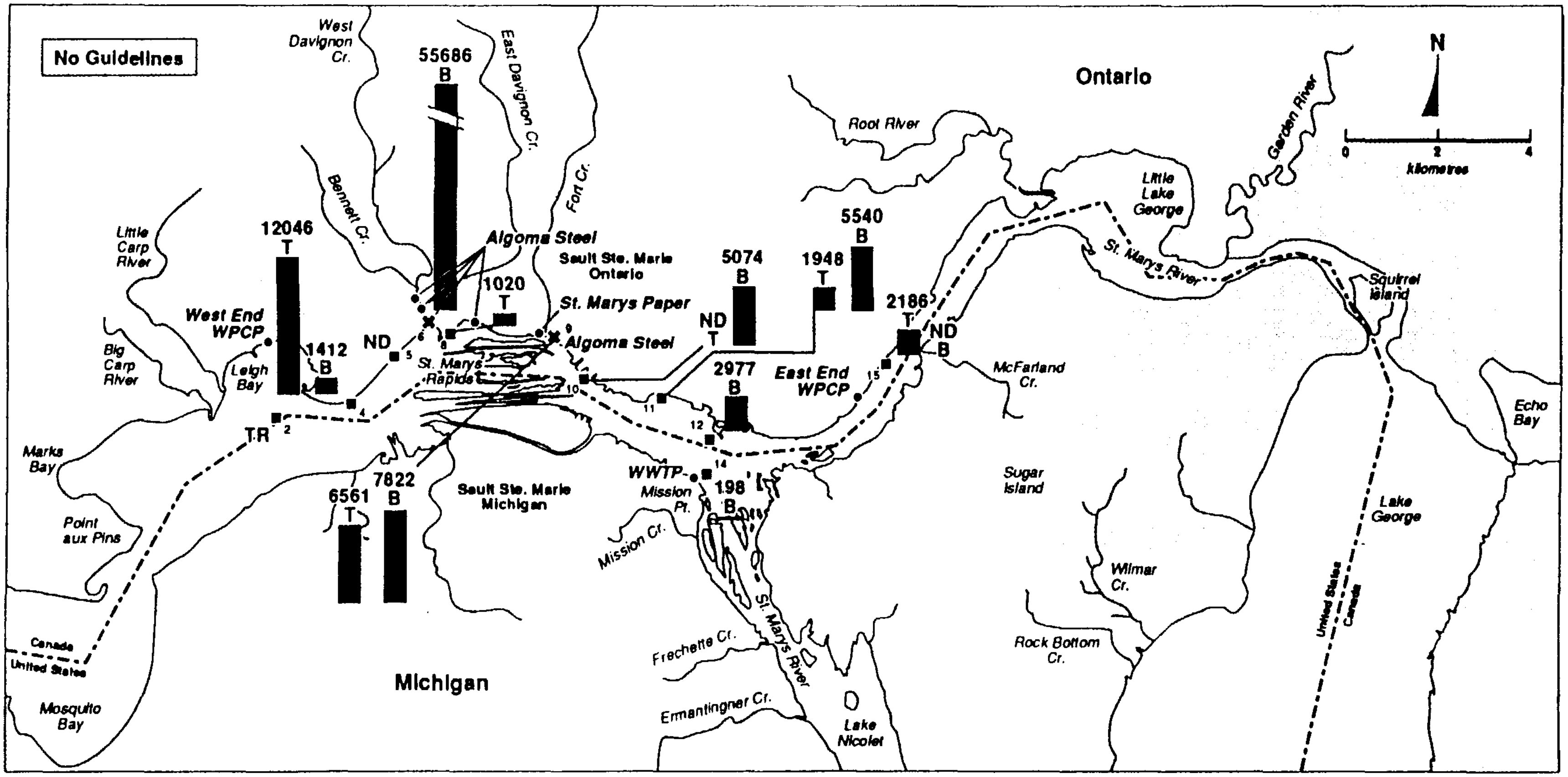
Figure 6.7

St. Marys River Remedial Action Plan

Total PAHs (ng/g dry weight) associated with centrifuged particulate matter in the St. Marys River, 1986

See Appendix 6.1, Table 6APP.2 for data

(from UGLCCS 1988)



✖ sampling and point source discharge location
• point source discharge location
■ sampling location

3205 — total PAHs (ng/g dry weight)
B — sample taken 0.5 m off bottom
Not Detected — ND
sample taken 1.5 m below surface — T

Table 6.3 Benzo(a)pyrene and total PAHs associated with the particulate phase, aqueous phase and estimated whole water in the St. Marys River, 1986 (from UGLCCS 1988) (See Appendix 6.1: Tables 6APP.2, 6APP.3 and 6APP.4 for full data set). (See Figure 6.7 for station locations).

Phase and Parameter	Stations																
	1	2	4		5	6	8	9		10		11		12	14	15	
		T	T	B	B	B	T	T	B	T	B	T	B	B	B	T	B
Particulate phase (ng/g dry wt)																	
Benzo(a)pyrene	ND	ND	593	ND	ND	3,882	67	465	650	ND	ND	ND	535	283	ND	ND	ND
Total PAHs	TR	TR	12,046	1,412	ND	55,686	1,020	6,561	7,822	ND	5,074	1,948	5,540	2,977	198	2,186	ND
Aqueous Phase (ng/L)																	
Benzo(a)pyrene	NA	NA	0.54	NA	NA	3.54	0.06	0.42	0.59	NA	NA	NA	0.49	0.26	NA	NA	NA
Total PAHs	NA	NA	26.57	9.49	NA	1,946.54	46.05	507.83	399.23	NA	16.89	870.14	317.88	132.27	1.11	87.15	NA
Whole Water (ng/L)																	
Benzo(a)pyrene	NA	NA	1.19	NA	NA	140.96	0.56	3.87	5.40	NA	NA	NA	2.15	0.29	NA	NA	NA
Total PAHs	NA	NA	39.81	11.04	NA	3,891.94	53.63	556.38	457.12	NA	53.84	875.20	335.04	132.57	1.48	94.32	NA

ND = Not Detected
NA = Not applicable as PAHs were not detected on the centrifuged particulate matter
TR = Trace

T = Sample taken 1.5 m below surface
B = Sample taken 0.5 m off bottom

water at this station ranged between 0.02 ng/L and 1,414 ng/L (Appendix 6.1: Table 6APP.4).

- At Station 9, immediately downstream of the Algoma Steel Terminal Basins discharge, total PAHs on suspended particulates at 1.5 m (6,561 ng/g) and 0.5 m off-bottom (7,822 ng/g) were similar, owing to vertical mixing (Figure 6.7 and Table 6.3). The estimated total PAH concentrations associated with the aqueous phase were 508 ng/L and 399 ng/L in surface and off-bottom samples, respectively (Table 6.3). Equivalent whole water total PAH concentrations were 556 ng/L and 457 ng/L, respectively, both of which exceeded the U.S. EPA criterion of 31 ng/L. The estimated concentration of benzo(a)pyrene associated with the whole water phase averaged 5 ng/L.

- At Station 11, located in a sheltered embayment, total PAHs associated with centrifuged particulate matter were much greater at the bottom than at the surface (Figure 6.7 and Table 6.3), reflecting the effects of a depositional zone. The estimated concentration of total PAHs in the aqueous and whole water phases of the near-bottom sample were 318 ng/L and 335 ng/L respectively. The latter exceeded the U.S. EPA criterion.

- In general, high PAH levels associated with the suspended particulate fraction persisted as far as Sault Ste. Marie's East End WPCP (Figure 6.7). For example, in the surface waters of Station 15, which is immediately downstream from the WPCP's discharge, total PAHs associated with the particulate fraction were 2,186 ng/g in surface waters (Table 6.3). PAHs at 0.5 m off bottom were not detected, indicating the buoyant nature of the WPCP effluent. The estimated total PAH concentration associated with the whole water phase at this location was 94 ng/L, again exceeding the U.S. EPA limit.

- Along the Michigan shoreline, downstream of the Sault Edison Electric Company Canal and the WWTP, the total PAH concentration associated with centrifuged particles was 198 ng/g (Figure 6.7 and Table 6.3). The estimated concentrations of total PAH in the aqueous and whole water phases were 1.11 ng/L and 1.48 ng/L respectively, considerably lower than levels identified along the Ontario shoreline, and well below the U.S. EPA criterion of 31 ng/L. Benzo(a)pyrene was not detected.

- Total PAHs exceeded the U.S. EPA AWQC in the Algoma Slip (3,891.94 ng/L) and downstream from the Slag Site, along the Ontario shore to 1 km downstream of the East End WPCP. Values ranged from 39.81 to 875.20 ng/L.

Several PAH compounds are of environmental concern because they are mutagenic or their metabolites are carcinogenic. The mutagenicity and carcinogenicity of 29 PAH compounds is shown in Table 6.4. Dimethylbenz(a)anthracene, benzo(a)pyrene and dibenzo(a,h)anthracene are the most carcinogenic compounds.

The 1986 water sampling survey showed that 95% of the PAH compounds detected in the aqueous phase are not carcinogenic or are only weakly carcinogenic. Estimates of PAHs associated with both whole water and the aqueous phase that are considered to be non-carcinogenic constitute greater than 80% of total PAHs at all sites sampled along the St. Marys River in 1986. Benzo(a)pyrene, a carcinogenic PAH compound, was detected in the aqueous phase of the water column downstream from the Algoma slag site, along the Ontario shore to where the river forks around Sugar Island.

Table 6.4 Mutagenicity and carcinogenicity of twenty-nine polycyclic aromatic hydrocarbons (PAHs) (Kauss and Hamdy 1991).

PAH Compound	Mutagenicity	Carcinogenicity
Naphthalene	-	-
Acenaphthylene	-	-
Acenaphthene	+	-
Fluorene	-	-
Phenanthrene	-	-
Anthracene	-	-
Fluoranthene	ND	-
Pyrene	-	-
Chrysene	+	$\pm$
Benzo(a)anthracene	+	+
Benzo(b)fluoranthene	ND	+ +
Benzo(k)fluoranthene	ND	-
Benzo(j)fluoranthene	ND	+ +
Benzo(e)pyrene	+	$\pm$
Perylene	ND	-
Dimethylbenz(a)anthracene	ND	+ + + +
Benzo(a)pyrene	+	+ + +
Indeno(1,2,3-c,d)pyrene	ND	+
Dibenzo(a,h)anthracene	+	+ + +
Benzo(g,h,i)perylene	ND	-
Anthanthrene	ND	ND
Benzo(b)chrysene	ND	ND
Coronene	ND	-
Quinoline	+	+
Carbazole	ND	-
Acridine	+	-
Benz(a)acridine	+	ND
Benzothiophene	ND	ND
Dibenzothiophene	ND	ND

Notes: 1) Information on mutagenic and carcinogenic properties is from Verschueren (1983): Oehme (1985); and from U.S. National Academy of Sciences, reported in National Research Council (1983).

2) Carcinogenicity ranking is: - not carcinogenic;
$\pm$ uncertain or weakly carcinogenic;
+ carcinogenic; and
+ +, + + +, + + + + strongly carcinogenic

ND No data available from the above references

6.1.3 Bacteria

6.1.3.1 Background

Bacteriological water quality indicators are groups of bacteria whose densities can be related quantitatively to the presence of sewage or fecal matter, and therefore to the risk of contracting a disease from the pathogens contained therein. Ontario considers that recreational waters are impaired for swimming and bathing when total coliform (TC), fecal coliform (FC), and/or fecal *streptococcus* (FS) geometric mean densities exceed 1,000, 100 and/or 20 organisms per 100 mL respectively, in a series of at least 10 samples per month, including weekend collections (OMOE 1984). Where the ratios of fecal coliforms to fecal streptococci (calculated from geometric means) exceeds 4.0, the source of bacterial contamination is likely to be human in origin. A ratio of less than 0.7 indicates non-human sources. The Michigan Water Quality Standard is 200 fecal coliform organisms per 100 mL, calculated as the geometric average of any series of 5 or more consecutive samples taken within a 30 day period.

Pseudomonas aeruginosa is a pathogen to man and animals, and can cause a variety of infections, including skin rashes and swimmers' ear (otitis externa). According to physicians, the chances of swimmers acquiring otitis externa is five times greater than for the general population. *Pseudomonas aeruginosa* appears to be quite resistant to chlorination. Perhaps of greater concern is that this organism is quite resistant to anti-bacterial agents in general (Dutka 1973), which is a major problem in the therapeutic treatment of infections.
The Great Lakes Water Quality Agreement (IJC 1988a) does not specify a numerical objective for microbiological organisms, but does provide a narrative criterion stating that waters should be substantially free from infectious bacteria, fungi, and viruses.

High bacterial densities were first detected in the St. Marys River in 1909 (IJC 1914). In 1947 and 1948, the IJC again found high levels of bacteria (IJC 1951). In 1973 and 1974 and again in 1986 and 1987, bacteriological samples were taken at selected transects (ranges) within the St. Marys River to determine ambient conditions and relate them to Ontario and GLWQA objectives. Where applicable, each sampling transect extended from the United States to the Canadian shore (Figure 6.8). Along each transect, three to six samples were collected daily on May 29 to June 5, July 25 to 29 and October 12 to 18, 1973 and on April 26 to 29, June 16 to 20 and August 18 to 24, 1974. Similar sampling was carried out between June 17 to 19, 1986 and May 12 to 14 and September 14 to 16, 1987. Values from all surveys are presented as geometric means. Stations that showed similar geometric means were grouped together, labelled and contoured provided they were not separated by a geographic barrier and that the variances were similar and the data normally distributed (Luck and Young 1978).

6.1.3.2 1973 Surveys

In May to June of 1973, the entire upper reach of the St. Marys River above the locks had very low mean TC densities of 5/100 mL (Group A, Figure 6.9). Downstream from the locks on the Ontario side, the density increased to 66/100 mL (Group B), whereas on the Michigan side, the TC level was 26/100 mL (Group D). FC densities were homogenous throughout the river at 3/100 mL. Densities of FS were higher than FC numbers below the locks on the Ontario side, suggesting a non-human source of contamination. Overall, however, levels were well below the Ontario PWQO for swimming and bathing.

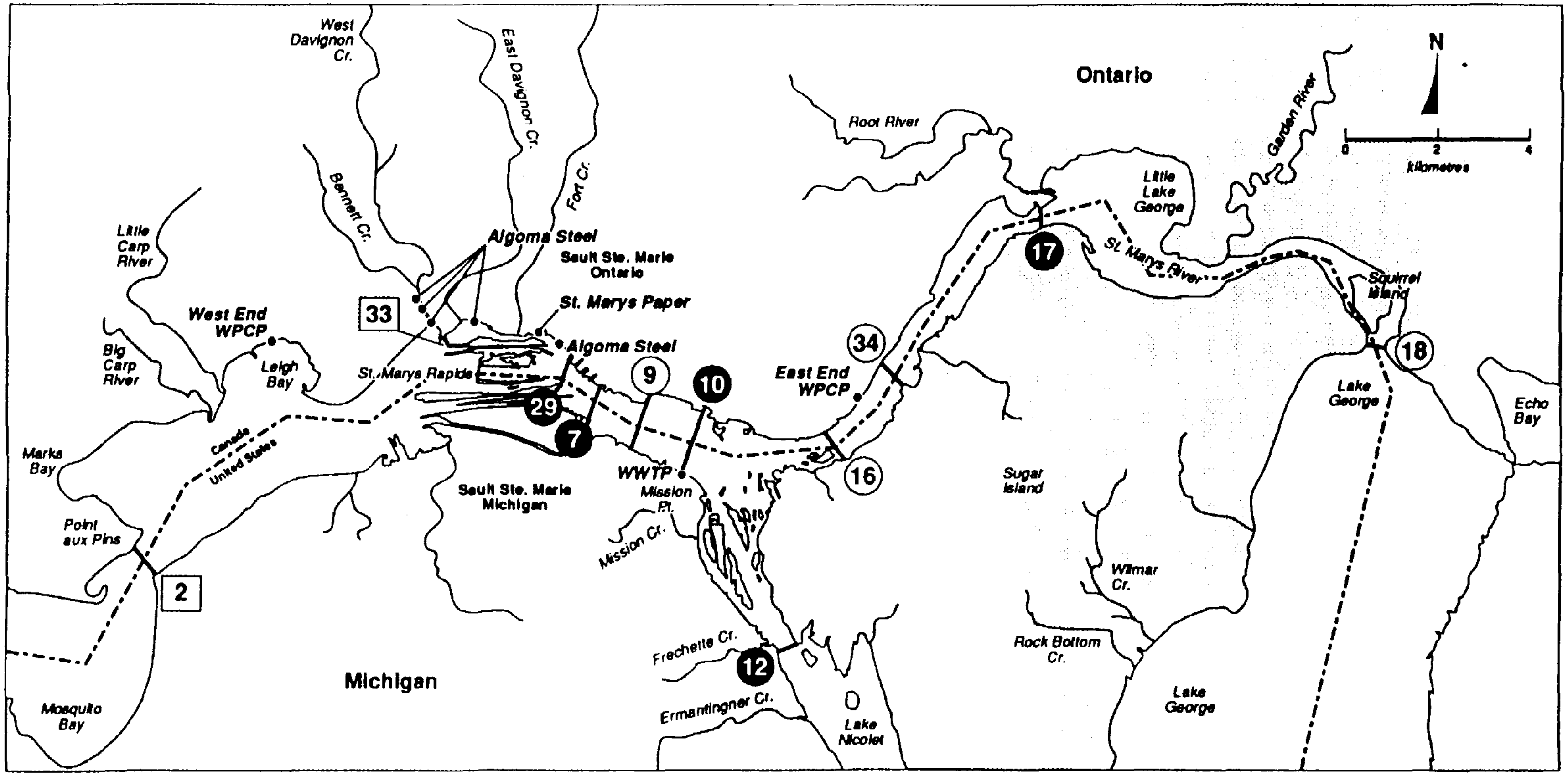
In July, densities of TC and FC were 133/100 mL and 16/100 mL respectively, (Group A, Figure 6.10) at all upstream stations and most of those downstream along the Michigan side of the river. In contrast, higher densities of TC bacteria (1670/100 mL) characterized most of the downstream stations on the Ontario side and inflowing waters to Lake Nicolet (Group B). The somewhat higher FC than FS densities associated with

Figure 6.8

St. Marys River Remedial Action Plan

Location of sampling transects for the 1973 and 1974 bacteriological surveys of the St. Marys River

(from Luck and Young 1978)



— transects

2 sampled in 1973

9 sampled in 1974

29 sampled in 1973 and 1974

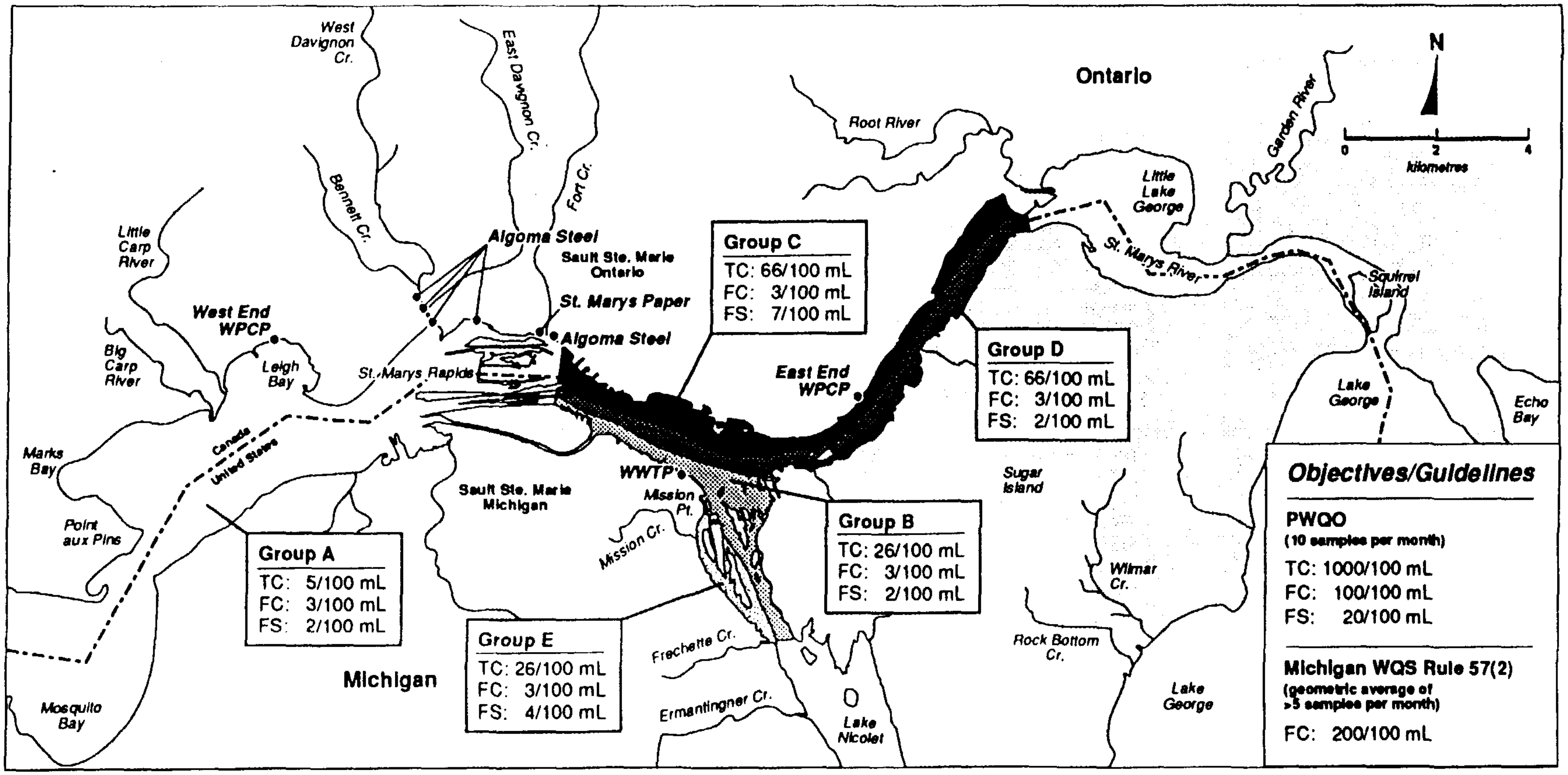
• point source discharge location

Figure 6.9

St. Marys River Remedial Action Plan

Bacteriological conditions in the St. Marys River, May 29 to June 5, 1973

(from Luck and Young 1978)



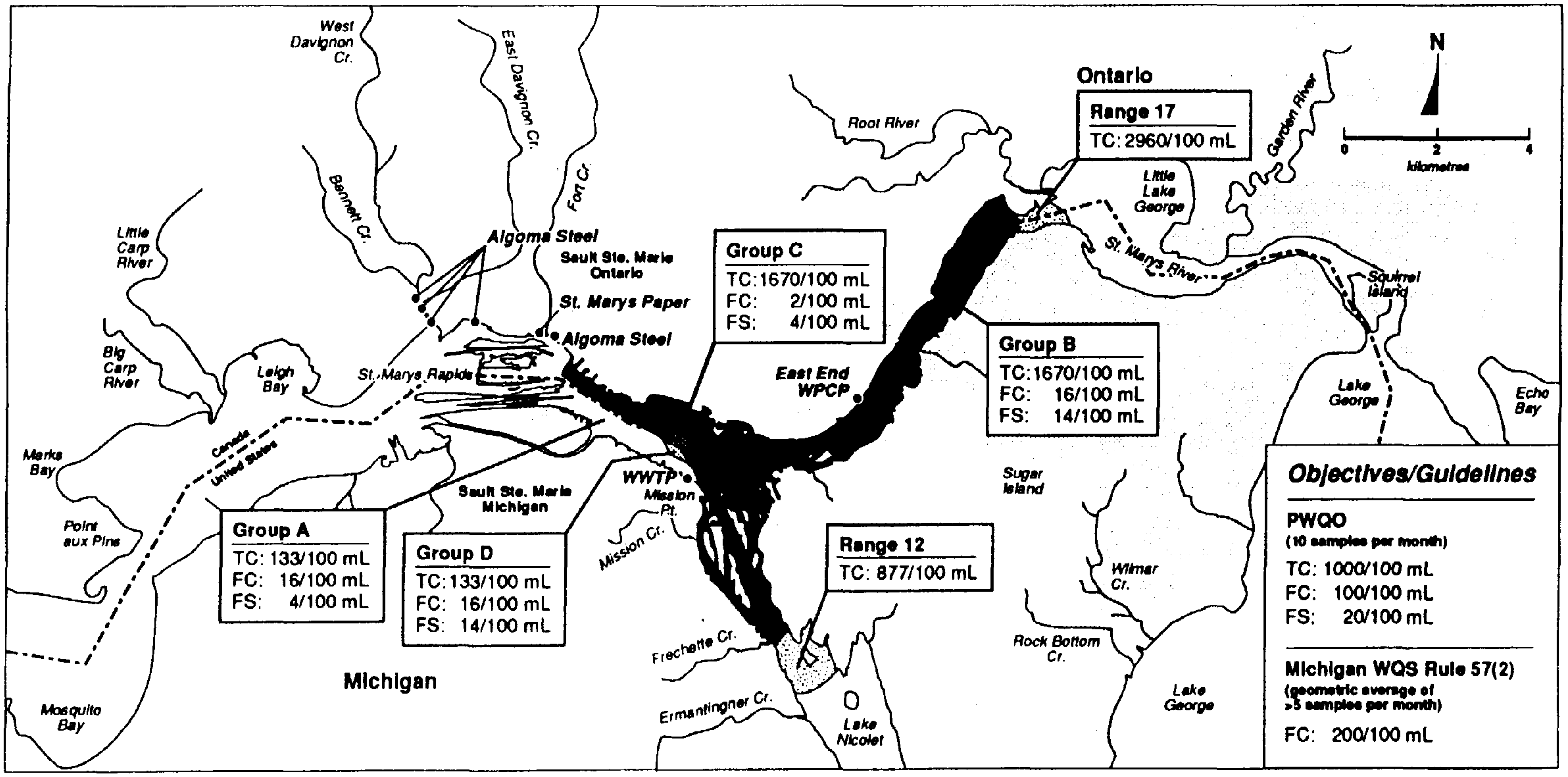
• point source discharge location

Figure 6.10

St. Marys River Remedial Action Plan

Bacteriological conditions in the St. Marys River, July 25 to July 29, 1973

(from Luck and Young 1978)



• point source discharge location

Groups A and B suggested that contamination was mainly of human origin. The area at the end of the Lake George Channel had TC and FC densities of 2,960/100 mL and 22/100 mL respectively. The higher TC levels relative to most upstream densities might have resulted from a combination of nutrient enrichment and discharges from the WPCP located on the Ontario shore (Luck and Young 1978). This high TC density, as well as that below the locks on the Ontario side (Group C), exceeded the Ontario PWQO (1000 TC/100 mL).

In October, most upstream stations as well as those closest to the Michigan shore below the locks had a TC density of 102/100 mL and 10 FC/100 mL (Group A, Figure 6.11), while the downstream Ontario water had a density of 312 TC/100 mL (Groups B and D). Nevertheless, bacterial levels were always less than Ontario PWQO for recreational use. TC densities did not exceed the Michigan WQS (200 FC/100 mL).

6.1.3.3 1974 Survey

The April survey, conducted downstream of the locks (Figure 6.12) showed that Michigan waters had bacterial densities of 10 TC/100 mL, 2 FC/100 mL and 2 FS/100 mL (Group A). On the Ontario side, downstream from the locks to where the river splits around Sugar Island (Group B), densities were slightly higher (72 TC/100 mL, 17 FC/100 mL and 2 FS/100 mL). Further downstream to Bell Point, FC densities were higher than FS densities, indicating contamination of human origin from the Ontario side and the East End WPCP. However, densities for all three parameters did not exceed Ontario objectives for recreational use.

In June, 1974 (Figure 6.13) bacterial levels in Ontario waters were much higher than those of Michigan. Stations along the Michigan shore (Group A) had TC, FC and FS densities of 15/100 mL, 3/100 mL and 3/100 mL, respectively, while Ontario waters downstream to Hog Island had mean concentrations of 153 TC/100 mL, 3 FC/100 mL and 14 FS/100 mL (Group B). At one of the sampling stations in Group B, station 10, 3.2 km downstream of the locks, very high densities of 2,960 TC/100 mL, 364 FC/100 mL and 386 FS/100 mL occurred. Both Ontario's PWQO for TC and FC and Michigan's FC objective were exceeded at station 10. Elevated *Pseudomonas aeruginosa* densities of 93 organisms/100 mL were also found here confirming water quality deterioration around this area and the presence of recent fecal inputs (Luck and Young 1978). Lower bacterial densities were found in downstream waters (Group C).

During the August survey (Figure 6.14), waters along the Sault Ste. Marie, Ontario shoreline (Group D) had TC, FC and FS densities of 272/100 mL, 27/100 mL, and 24/100 mL, respectively. Michigan waters downstream of the Sault Edison Electric Company Canal (Group G) had FS densities of 21/100 mL. Both areas (Groups D and G) had FS densities that exceeded the PWQO of 20/100 mL. Elevated levels of *Pseudomonas aeruginosa* (23/100 mL) also occurred in both areas. The downriver area around Palmers Point and Squirrel Island (Group B) had a higher TC level of 352/100 mL. Michigan waters and part of the channel leading to Little Lake George (Group A) had densities of TC, FC, and FS of 100/100 mL, 27/100 mL and 4/100 mL, respectively. Most waters surveyed had *Pseudomonas aeruginosa* densities of 3/100 mL.

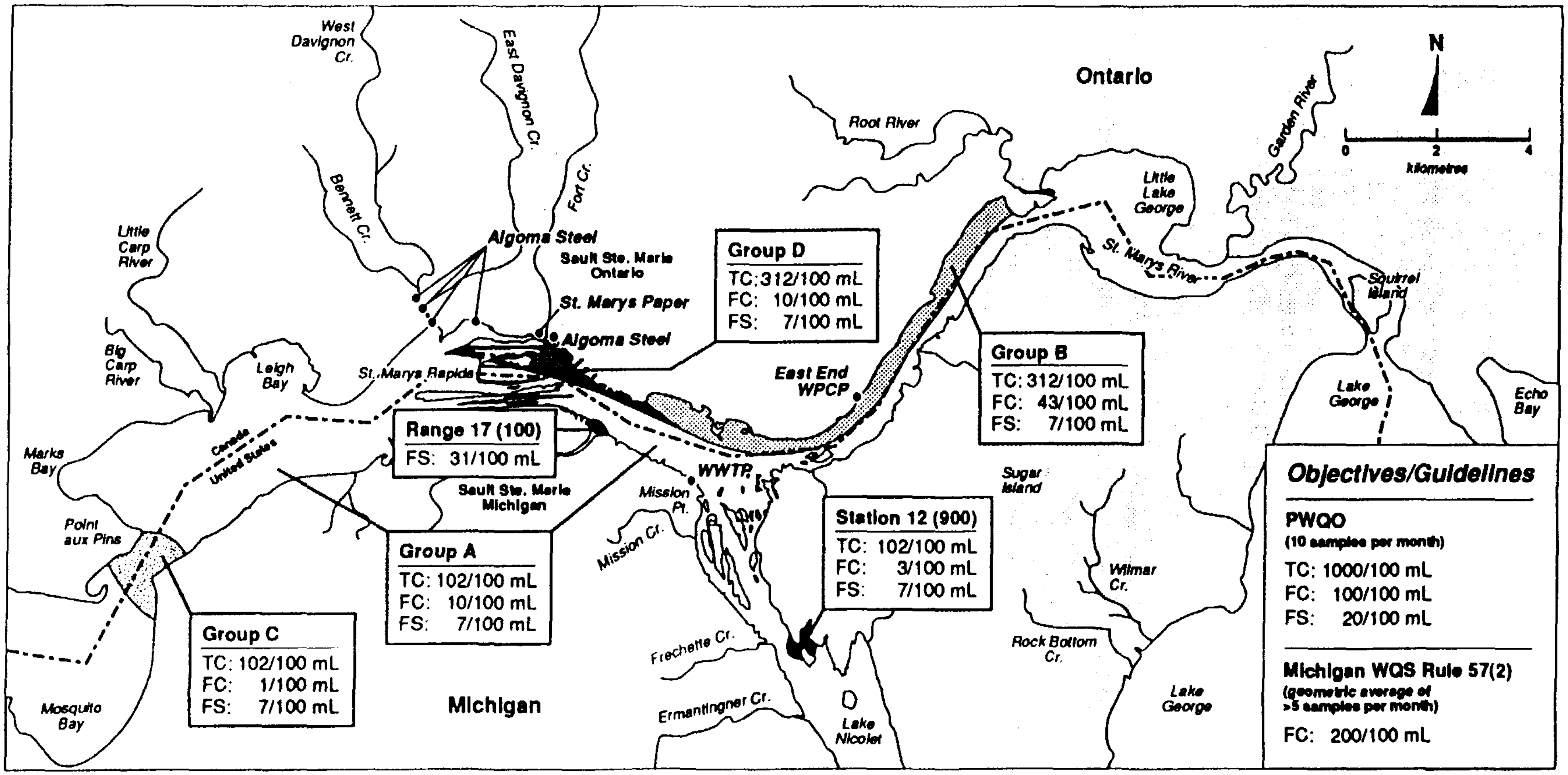
Based on these 1973 and 1974 survey results, Ontario and Michigan criteria were sometimes exceeded in both years along the Ontario shore between the locks and the government dock. Furthermore, the presence and 1974 PWQO exceedence of *Pseudomonas aeruginosa* indicated that a health hazard could exist for people using the water. In general, OMOE concluded that bacterial levels throughout the river were usually below provincial objectives for recreational water use and densities were kept from increasing due to the continuous flushing of the river with clean water from Lake Superior.

Figure 6.11

St. Marys River Remedial Action Plan

Bacteriological conditions in the St. Marys River, October 12 to 18, 1973

(from Luck and Young 1978)



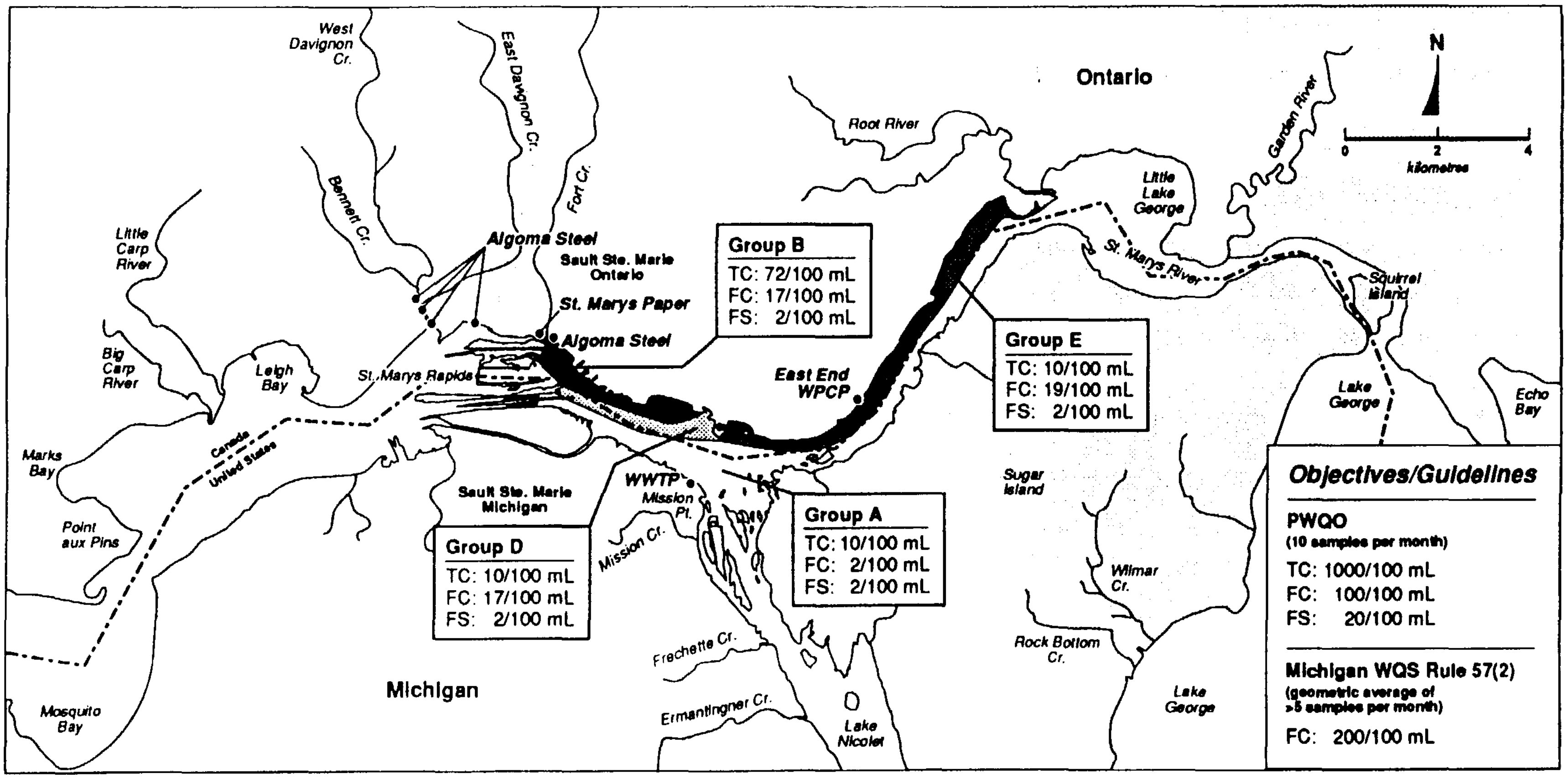
• point source discharge location

Figure 6.12

St. Marys River Remedial Action Plan

Bacteriological conditions in the St. Marys River, April 26 to 29, 1974

(from Luck and Young 1978)



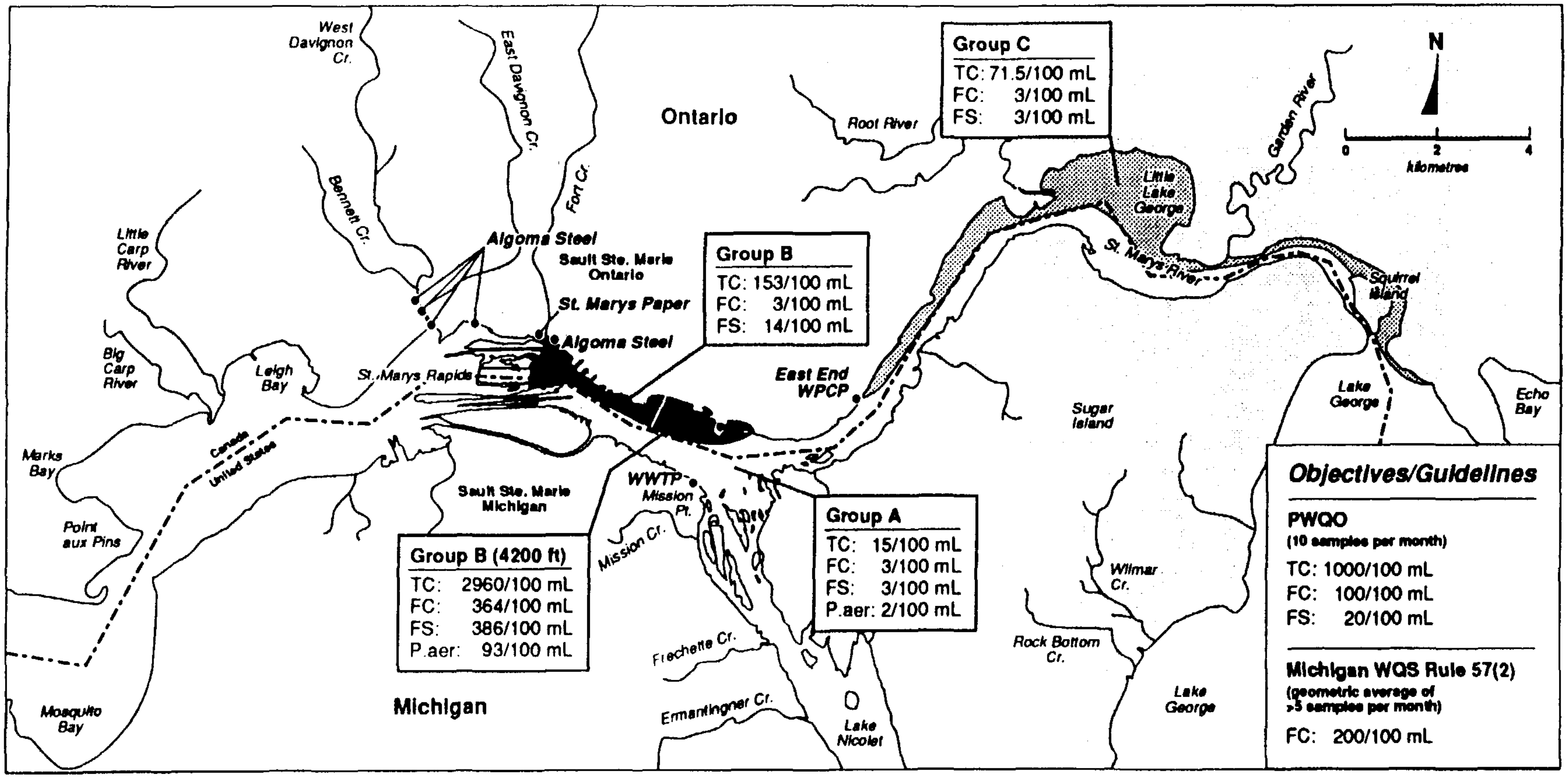
• point source discharge location

Figure 6.13

St. Marys River Remedial Action Plan

Bacteriological conditions in the St. Marys River, June 16 to 20, 1974

(from Luck and Young 1978)



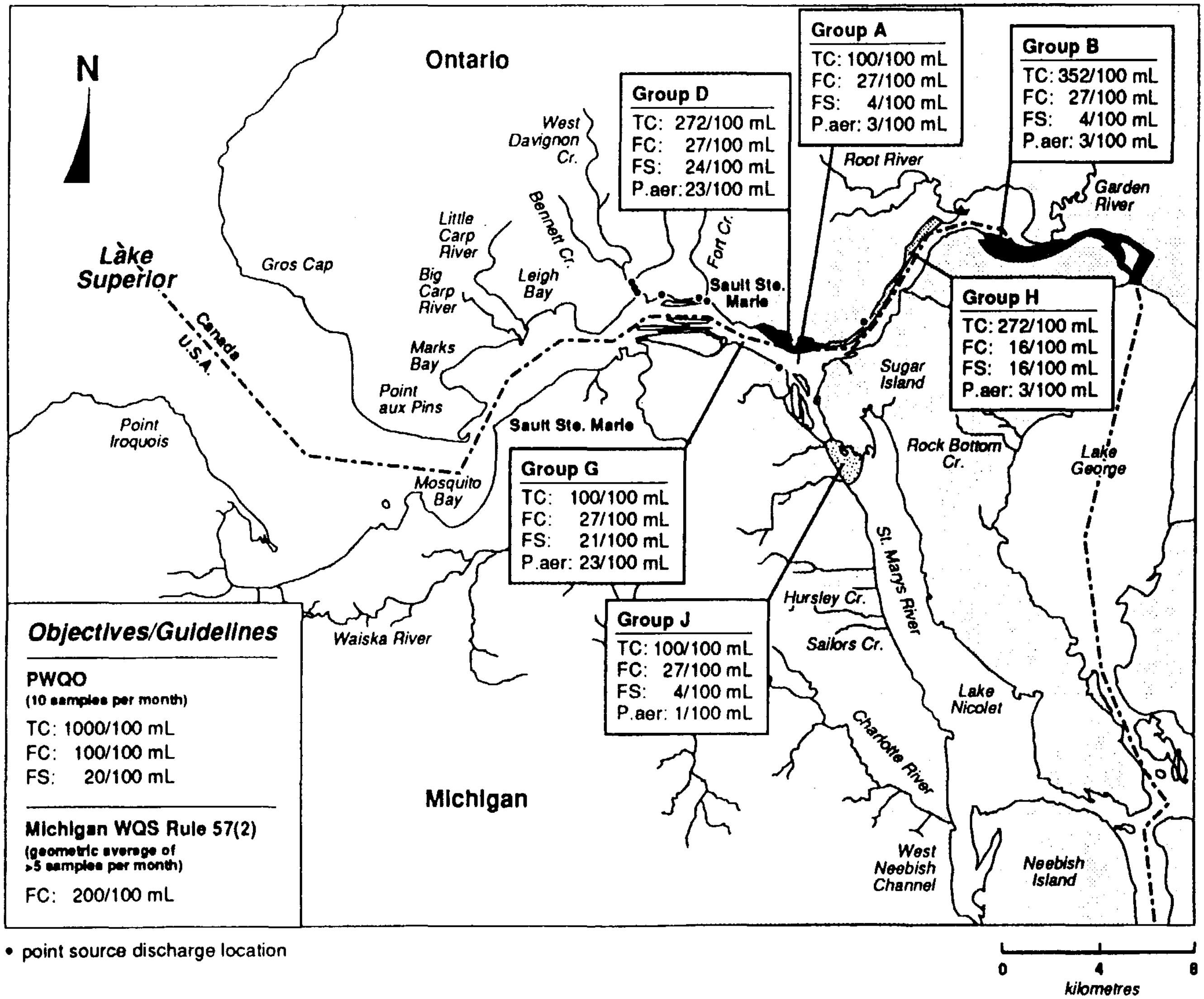
• point source discharge location

Figure 6.14

St. Marys River Remedial Action Plan

Bacteriological conditions the St. Marys River, August 18 to 24, 1974

(from Luck and Young 1978)



• point source discharge location

6.1.3.4 1986 and 1987 Surveys

The June, 1986 survey showed that geometric mean densities of FC exceeded both the PWQO of 100 organisms/100 mL and the Michigan WQS of 200 organisms/100 mL downstream of storm sewers and major industrial outfalls along the Ontario shoreline. For example, at ranges SMD 0.8 and SMD 1.0 (see Figure 6.1 for locations), mean FC densities over 3 days were 477/100 mL and 428/100 mL, respectively. A further 1.5 km downstream, densities were below the PWQO (UGLCCS 1988).

Bacterial densities were also elevated below the outfall of the Sault Ste. Marie, Ontario East End WPCP. Mean densities over the 3-day June survey at ranges SMD 5.0E and SMD 7.9E were: FC, 184/100 mL and 182/100 mL; FS, 24/100 mL and 19/100 mL; and *Pseudomonas aeruginosa*, 5/100 mL and 7/100 mL, respectively. The FS density at range SMD 5.0E (24/100 mL) exceeded the PWQO of 20 FS/100 mL. In Michigan waters, densities of fecal coliform, and fecal *Streptococcus* were well below the respective Ontario objectives at all locations, except for those immediately downstream from the Sault Edison Electric Company Canal. Because only 3 samples were collected from this site during the June, 1986 survey, comparison with Michigan water quality standards is not possible. However, the 3-day geometric means of *E. coli*, fecal coliform, fecal *Streptococcus* and *Pseudomonas aeruginosa* were 2,250 organisms, 233 organisms, and 20 organisms, respectively, per 100 mL. Combined sewer overflows which discharge to the Edison Power Canal are suspected as the source of this bacterial contamination (UGLCCS 1988).

Additional bacteriological sampling carried out in 1987 during May and September showed similar trends to those described for 1986. Further sampling was undertaken in the Lake George Channel in 1989 by OMOE to determine the impact of the East End WPCP following upgrading of the sewage treatment process (improved phosphorus and solids removal). Results of this investigation have not yet been published, but indicate exceedences of the PWQO for FC downstream of the plant's outfall as far as Bells Point, as well as the presence of *Pseudomonas aeruginosa* and *E. coli* (OMOE unpublished data).

More recently, the Federal-Provincial Working Group on Recreational Water Quality has stated that the source of bacterial contamination cannot be defined using the FC/FS ratio. FS densities could be greater than those for FC due to the fact that streptococci are more resistant to extremes of temperature and to chlorine, and have a greater longevity than coliforms. Nutrient rich waters and non-point sources can cause proliferation of FC levels and bear no relation to the human origin of coliforms (Guidelines for Recreational Water Quality, DSS, 1983, also 1991-draft).

The RAP Team will seek the advice of this working group before proceeding with the analysis of any data collected after the 1987 survey. The analysis of the surveys reported in the RAP document may need to be revisited.

6.1.3.5 Beach Closures

In Michigan, total body contact advisories were periodically issued in 1989 by the Chippewa County Health Department in response to elevated fecal coliform levels caused by combined storm sewer overflows (MDNR 1990) however, there have been no official beach closings in Michigan because the Sherman Park Beach is located upstream of the combined sewer overflows.

No total body contact advisories have been issued by the Algoma Health Unit in Ontario.

6.1.4 Water Quality Summary

Concentrations of a number of basic physical and chemical parameters indicate that, overall, the St. Marys River is an oligotrophic system. However, in localized areas, some water quality standards or objectives are exceeded. Table 6.5 shows that dissolved oxygen, turbidity, total phenols, total and unionized ammonia, free cyanide, iron, total phosphorus, total PAHs, and bacteria have exceeded applicable PWQO, MWQS, GLWQA objectives and the U.S. EPA criteria for total PAHS. Free cyanide has not been exceeded since 1974 (Table 6.5) and 1986 surveys indicate that cyanide concentrations are below criteria.

The majority of the exceedences occur downstream of the locks which is downstream of the outfalls from Algoma Steel and St. Marys Paper. Storm sewers discharge to river downstream of the locks on the Ontario side and into the Sault Edison Power Canal on the Michigan side. Exceedences of dissolved oxygen, total phenols, iron and total PAHs occurred in the Algoma Slip.

Table 6.5 Summary of parameters exceeding water quality criteria in the St. Marys River Area of Concern.

Parameter	Guideline or Objective (mg/L)		Year and Location of Exceedence (mg/L)
Dissolved Oxygen	PWQO MWQS	4 (47%) - 8 (54%) 7.0	1985, October-Algoma Slip (0%; min)
Turbidity	PWQO	<10% change in Secchi disc readings	All ice-free seasons-In shallow depositional areas such as lower Lake George, western Munuscong Lake and southwest shore of Neebish Island
Total Phenols	PWQO GLWQA MWQS	0.001 0.001 0.110	1973 to 1986-300 metres downstream of Algoma Steel's Terminal Basins outfall (0.060 to 0.0012; range of means) 1970 to 1980-up to 3000 metres downstream of Terminal Basins outfall along the Ontario shore (0.019 to 0.003; range of annual means) 1986/87-4 km downstream of Terminal Basins outfall along the Ontario shore and laterally to U.S. waters (0.0015 and 0.0012; means near Ontario shore and 750 m from U.S. shore in U.S. waters respectively) 1986/1987-Algoma Slip and mouth of Algoma Slip (0.0036 and 0.0034 respectively; max)
Total Ammonia	GLWQA	0.50	1974-300 metres downstream of the Terminal Basins outfall along the Ontario shore (0.6 mg/L; mean) 1989-Exceedences up to 300 metres downstream of the East End WPCP (1.47-2.89; range of 4 samples)
Unionized Ammonia	PWQO MWQS	0.02 (Temp. and pH dependent) 0.02 (cold water) 0.05 (warm water)	1989-Exceedences up to 300 metres downstream of the East End WPCP (0.020-0.046; range of 4 samples)
Free Cyanide	PWQO MWQS AWQC	0.005 0.004 0.0052	1974, 1980-300 metres downstream of Terminal Basins outfall (0.3 and 0.06 respectively; means) 1974-One to six km downstream of Terminal Basins outfall (0.54 to 0.07; range of means) 1980-One to three km downstream of Terminal Basins outfall (0.01 to 0.02; range of means)
Iron	PWQO & GLWQA AWQC	 0.3 1.0	1986/1987-Immediately downstream of Terminal Basins outfall (0.69; max) 1986/1987-Algoma Slip (0.445/1.0; average/max)
Total Phosphorus	PWQO	0.03	1986/1987-Downstream of East End WPCP (0.051; max) 1989-Exceedences immediately downstream of the East End WPCP (OMOE unpublished data; values not provided) 1990-Excessive amounts of floating algae downstream of the East End WPCP (no measured values)
Total PAHs	AWQC	31 ng/L	1985-Algoma Slip (31.8 ng/L; one sample, aqueous phase) 1986-Algoma Slip (3,1891.94 ng/L; one sample) 1986-Downstream from Slag Site along Ontario shore to one km downstream of the East End WPCP (39.81 to 875.20 ng/L; range)

Table 6.5 (Cont'd)

Parameter	Guideline or Objective (mg/L)		Year and Location of Exceedence (mg/L)
Bacteria	PWQO	TC: 1000/100 mL FC: 100/100 mL FS: 20/100 mL	1973, July-Downstream of lock through channel to Little Lake George and channel to Lake Nicolet (2,960 TC,/100 mL; geometric mean) 1974, June-3.2 km downstream of lock (west of government dock) (2,960 TC/100 mL, 364 TC/100 mL, 386 FS/100 mL; one sample; geometric mean) 1974, August-Downstream of locks on Ontario and Michigan shore (24 and 21 FS/100 mL respectively; geometric mean) 1986, June-Downstream of locks along Ontario shore (477 FC/100 mL; 3 day mean) Downstream of East End WPCP (24 FS/100 mL; 3 day mean) 1989- Downstream from East End WPCP to Bells Point (FC; unpublished data)
	MWQS	FC: 200/100 mL	

PWQO Provincial Water Quality Objective for the Protection of Aquatic Life (OMOE 1984)
GLWQA Great Lakes Water Quality Agreement Objective (Chapter 4)
MWQS Michigan Water Quality Standard, Rule 57 Value (January 1991 version)
AWQC U.S. EPA Ambient Water Quality Criteria

In the Algoma Steel Slip, bottom waters were devoid of dissolved oxygen during a biological monitoring study undertaken in October of 1985. With this exception, dissolved oxygen levels are almost always greater than 90% throughout the AoC. During summertime in shallow embayments, diminished concentrations can occur as a result of natural processes.

High turbidities in sections of the lower St. Marys River (Table 6.5) are produced naturally from fine clays suspended in the water column by currents (runoff from local watersheds plus river flows), wave action, and to a lesser degree re-suspension of bottom materials from shipping activities.

Long-term water quality monitoring has shown that concentrations of some contaminants associated with industrial (Algoma Steel and St. Marys Paper) and municipal sewage treatment plant discharges, particularly, phenols, ammonia, free cyanide and some heavy metals, have steadily declined from the mid 1960's in the St. Marys River downstream from Sault Ste. Marie, Ontario. The improvements are attributable to: reductions of phenols, ammonia-nitrogen and free cyanide at Algoma Steel and dilution due to the re-development of the Great Lakes Power Corp. hydroelectric facility in 1982 (now the Clerque Generating Station) which resulted in substantially increased flows along the Ontario shoreline. However, downstream waters have only partially recovered from these improvements and it must be noted that dilution cannot be used to reduce downstream loadings. Discharges from the Sault Ste. Marie, Ontario East End WPCP are delaying the complete restoration of satisfactory water quality with respect to several contaminants including ammonia and total phosphorus.

Some transboundary contamination of Michigan waters occurs 4 km (station SMD 2.6) downstream of the Terminal Basins outfall owing to phenol levels which slightly exceed the PWQO and GLWQA objective of 0.001 mg/L. Mean concentrations range from 0.0012 to 0.0016 mg/L.

Water quality in and near the Algoma Steel Slip continues to be impaired. Maximum total phenol concentrations in 1986 within the slip and at the mouth of the slip were 0.0036 and 0.0034 mg/L respectively. The average iron level in the Slip in 1986 was 0.445 mg/L with a maximum of 1.0 mg/L. A whole water sample from the Algoma Slip in 1986 contained 3,891.94 ng/L total PAHs. All of these parameters exceeded their respective guidelines and objectives (Table 6.5).

Total phosphorus levels downstream of the East End WPCP exceeded the PWQO of 0.030 mg/L in 1986/1987 and 1989. Maximum concentrations in 1986 were 0.051 mg/L. 1989 values are not available. In 1990, excessive amounts of floating algae slow moving waters downstream of the East End WPCP were reported, indicating that phosphorus concentrations are likely being exceeded. The 1986/1987 survey also showed elevated levels of total ammonia occurred downstream of the East End WPCP. OMOE unpublished data reports that the PWQO and MWQS for unionized ammonia (0.02 mg/L) was exceeded in 1989, 300 metres downstream of the East End WPCP.

Measured PAHs, in 1985 and 1986, associated with the aqueous phase of the water column increased downstream of Leigh Bay, reaching their peak concentration in the Algoma Slip. In this phase, 95% of the PAH compounds measured are not carcinogenic or are only weakly carcinogenic. Estimates of PAHs associated with both the whole water and aqueous phase that are considered to be non-carcinogenic constitute greater than 80% of total PAHs at all sites monitored along the St. Marys River. Estimated concentrations of total PAHs associated with the whole water phase exceeded the U.S. EPA AWQC for Human Health Criteria (for fish consumption) of 31 ng/L for total PAHs from the Algoma Slag Site to downstream of the Sault Ste. Marie, Ontario East End WPCP.

Benzo(a)pyrene, a carcinogenic PAH compound, was detected in the aqueous phase of the water column downstream from the Algoma slag site, along the Ontario shoreline to where the river forks around Sugar Island.

The bacteriological surveys carried out by the OMOE indicate concentrations of fecal coliforms in excess of the PWQO immediately downstream from storm sewers and major industrial outfalls along the Ontario shoreline, and below the outfall of the East End WPCP. On the Michigan side, combined sewer overflows discharging into the Sault Edison Electric Company Power Canal resulted in FC densities in excess of applicable objectives and total body contact advisories.

Exceedences of fecal coliforms occurred downstream of East End WPCP as far as Bells Point (Little Lake George).

6.2 SEDIMENTS

6.2.1 Characteristics and Spatial Distribution

Bottom sediment is composed of all detrital, inorganic and organic material settling to the bottom of a body of water. The physical behaviour of sediment is strongly influenced by grain size and texture. Sediments with large particles, such as sand and coarser material >0.062 mm in diameter, are generally not associated with contaminated areas (IJC 1988b). Sediments composed of small particles, such as silt and clay with diameters <0.062 mm, are more reactive than coarser sediments and many inorganic and organic contaminants readily adsorb to the smaller sediment particles (IJC 1988b). Therefore, the spatial distribution of fine and coarse sediment throughout the St. Marys River AoC is important when assessing the potential areal extent of sediment contamination.

Sediment in the AoC has been divided into four categories based on particle size. These classes are described in terms of clay, silt, sand, and gravel or rock. The size assignment for each category is as follows:

Clay	<0.0039 mm in diameter
Silt	0.0039 - 0.062 mm in diameter
Sand	0.062 - 2.0 mm in diameter
Gravel or Rock	>2.0 mm in diameter

The particle size distribution of bottom sediment in the St. Marys River is shown in Figure 6.15.

In the upper river above St. Marys Rapids, sediments are composed of sand, along with rocks, cobbles, and gravel in Whitefish Bay. The Rapids area is characterized by gravel, rocks, boulders and exposed bedrock. Sediments in slower moving and less exposed areas of the lower river are composed mainly of sand and silt, or clay and silt (Figure 6.15). Closer to shore in the river's lower reach, sediments tend to be mainly clay with organic detritus with the proportion of sand increasing with distance offshore. The more protected shorelines tend to have finer sediments than the more exposed, eastern shores. Large portions of the dredged channel are dominantly comprised of clay (Kauss 1991).

Sediment composition 4 km downstream of the St. Marys Rapids, varies considerably from the Michigan to Ontario shorelines. The Michigan side consists of coarse to medium-fine sands which represent about 63% of the sediment's composition. In contrast, sediments along the Ontario shore, where several embayments exist, consist primarily of silts (82%) (Hesselberg and Hamdy 1987). In mid-river, fine to very fine sands and silts constitute about 90% of the sediment composition. This particle sorting can be attributed to the flow distribution in the river below the rapids. 69% of the total river flow is along the Michigan shoreline and 31% is along the Ontario side (Hesselberg and Hamdy 1987).

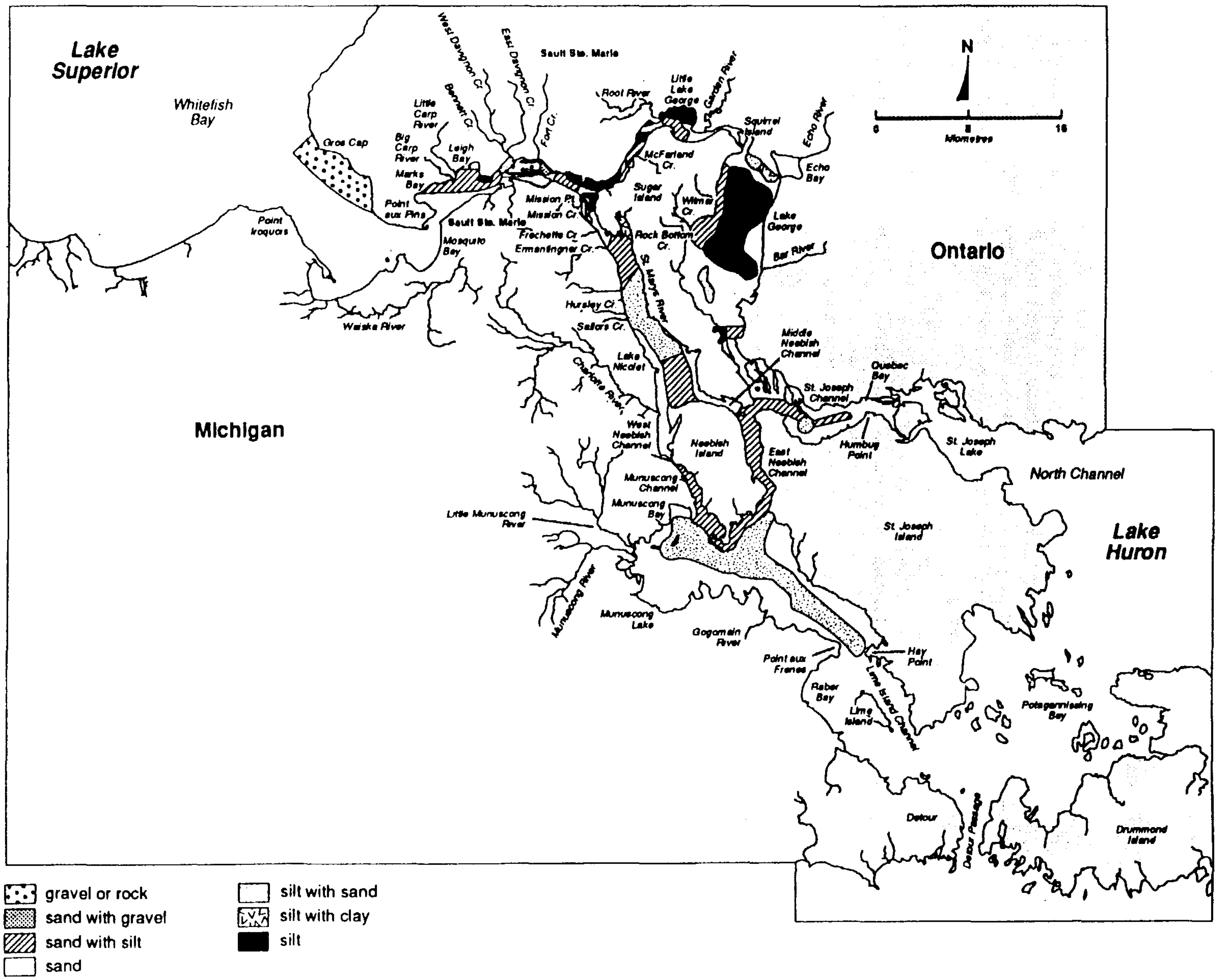
Sediment variation between shorelines also occurs in the channel separating Ontario and Sugar Island, Michigan. The curvature of the channel results in higher current velocities near the Island shoreline where medium to fine sand (82%) predominate. Lower velocities along the Ontario shore, result in a band of silty (47%) sediment (Hesselberg and Hamdy 1987).

Figure 6.15

St. Marys River Remedial Action Plan

Distribution of bottom sediment types in the St. Marys River Area of Concern

(prepared by MDNR from OMOE - U.S. EPA/FWS data collected in 1985 (Appendix 6.2) and USACOE (1970, 1972, 1982) and MDNR (1978) unpublished data)



The largest sediment depositional areas occur where the river deepens or widens and current velocities decrease. As a result, the finest suspended particles settle out. There are four large sediment depositional areas in the St. Marys River. These are Little Lake George, Lake George, Lake Nicolet and Munuscong Lake (Figure 6.15).

6.2.2 Historical Contamination

During the summer of 1986 in a joint project with Environment Canada, U.S. EPA and NOAA, OMOE collected two sediment core samples, each 60 cm in length, from near the centre of Lake George (stations 100 and 102, Figure 6.16) in order to determine the historical contamination of the river. Lake George was selected as the only site for core analysis because it represented an area with high sedimentation rates. At the time of this survey, limited time and analytical laboratory capacity affected the number of samples collected (Hesselberg and Hamdy 1987).

The sedimentation rates were determined by NOAA for both core samples by measuring the levels of cesium-137 (Cs-137) at various depths in the cores. The highest Cs-137 level occurred at a depth of approximately 15 cm (Figure 6.17). This high level corresponds to fallout from nuclear testing that peaked in 1962-1964 (UGLCCS 1988). The sedimentation rates were determined to be 0.22 $g/cm^2/yr$ (0.70 cm/yr) and 0.19 $g/cm^2/yr$ (0.53 cm/yr) at stations 100 and 102, respectively, with an average sedimentation rate of 0.6 cm/yr (Hesselberg and Hamdy 1987). The age of each layer within the core samples was subsequently determined. Only the core sample from station 102 was analyzed for contaminants by Environment Canada and OMOE.

6.2.2.1 Polychlorinated Biphenyls (PCBs) and DDT

PCBs first appeared in Lake George sediments in the 1950's, with maximum levels occurring in the mid-1970's (Figure 6.18). Production of this group of contaminants began in 1929 and peaked in 1970. The sediment analyses provide a reasonable record of its use.

DDT first appeared in the sediments deposited in the mid-1950's, with highest concentrations in the mid-1960's. Use of DDT began in 1944 in the United States, peaked in 1959, and was discontinued in 1971.

The highest concentrations of both contaminants in sediments occurred about 5 years following either peak production or use, and concentrations have declined in recent years (Figure 6.18). Major sources were likely remote and non-point, resulting in time delays in their transfer and disposition in river sediments. The low concentrations found in the core sediments provides additional support for diffuse and remote sources (Hesselberg and Hamdy 1987).

6.2.2.2 Polycyclic Aromatic Hydrocarbons (PAHs)

Lake George core sediment samples were analyzed for the following U.S.EPA priority PAHs:

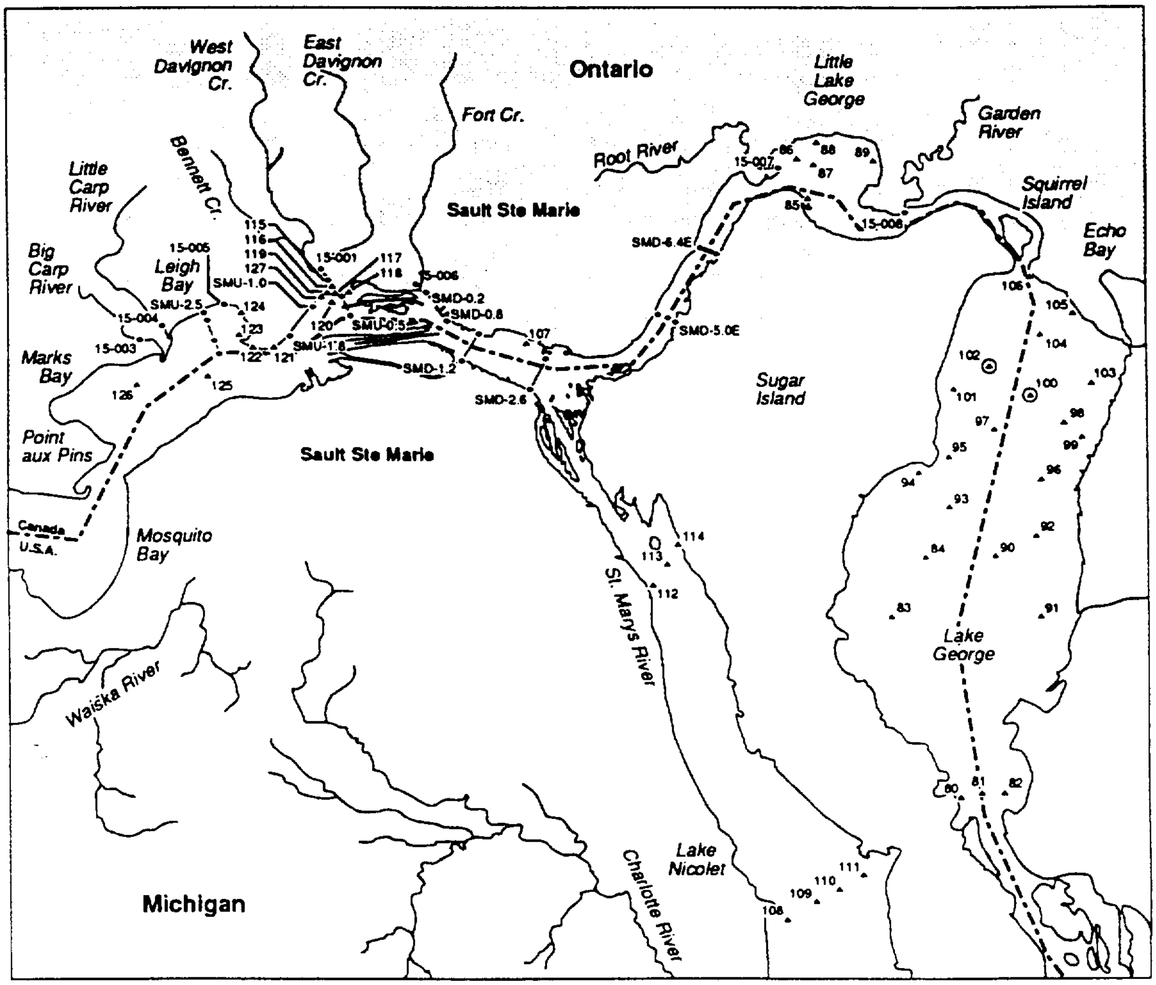
naphthalene (N)	benzo(b)fluoranthene (BbF)
acenaphthylene (AN)	benzo(k)fluoranthene (BkF)
fluoranthene (F)	benzo(a)pyrene (BaP)
pyrene (PY)	indeno(1,2,3-cd)pyrene (IP)
benzo(a)anthracene (BaA)	dibenzo(a,h)anthracene (DA)
chrysene (CH)	benzo(g,h,i)perylene (BP)

Figure 6.16

St. Marys River Remedial Action Plan

Location of the OMOE surface sediment sampling sites on the St. Marys River during 1985 and the location of two core samples from Lake George collected during the summer of 1986

(from Hesselberg and Hamdy 1987)



- St. Marys downstream (SMD)
- St. Marys upstream (SMU)
- ⊙ core sampling site
- ▴ sampling site

Figure 6.17

St. Marys River Remedial Action Plan

Variation with depth of Cesium-137 in Lake George core sediments collected in 1986

(UGLCCS 1988)

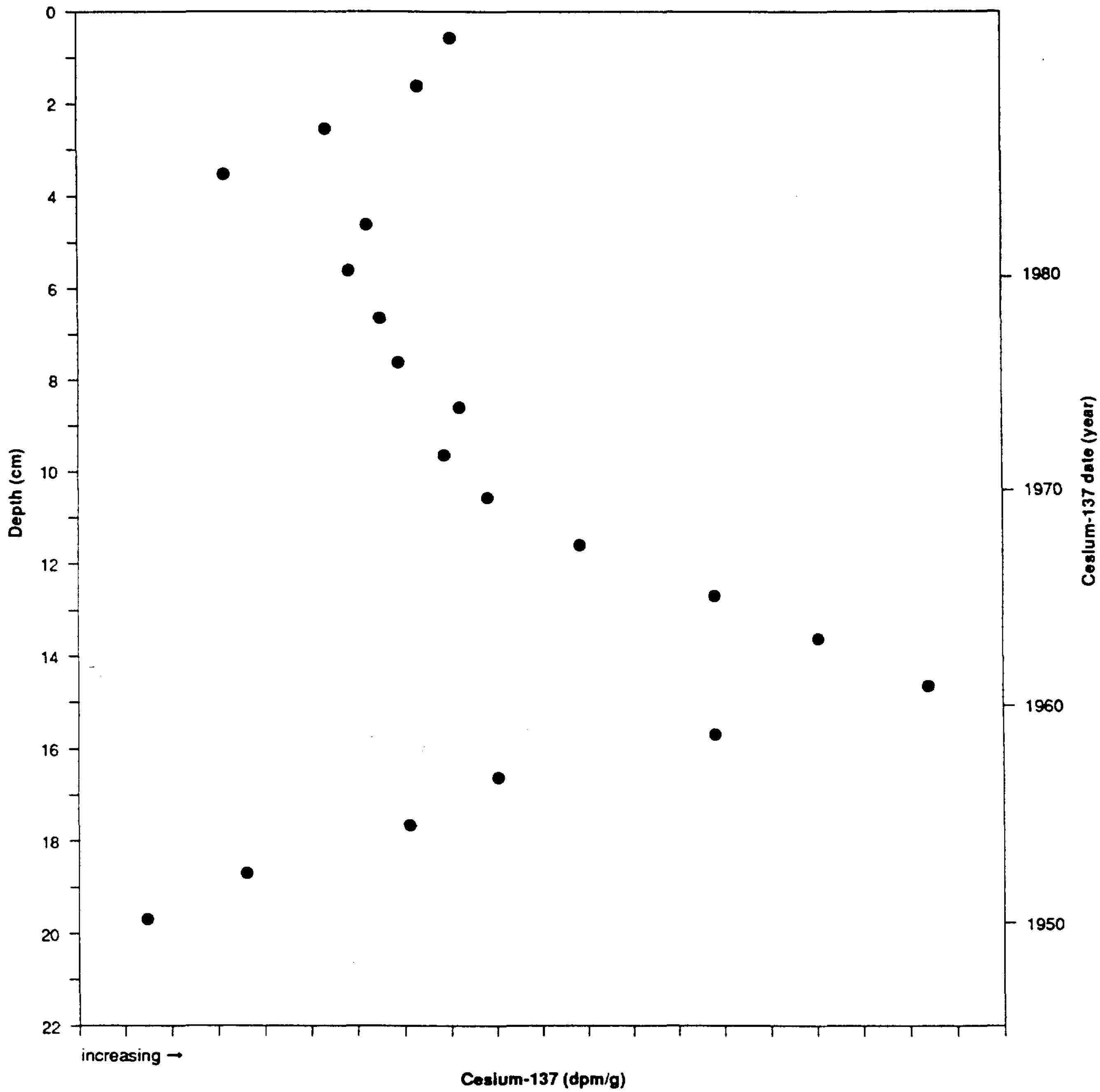


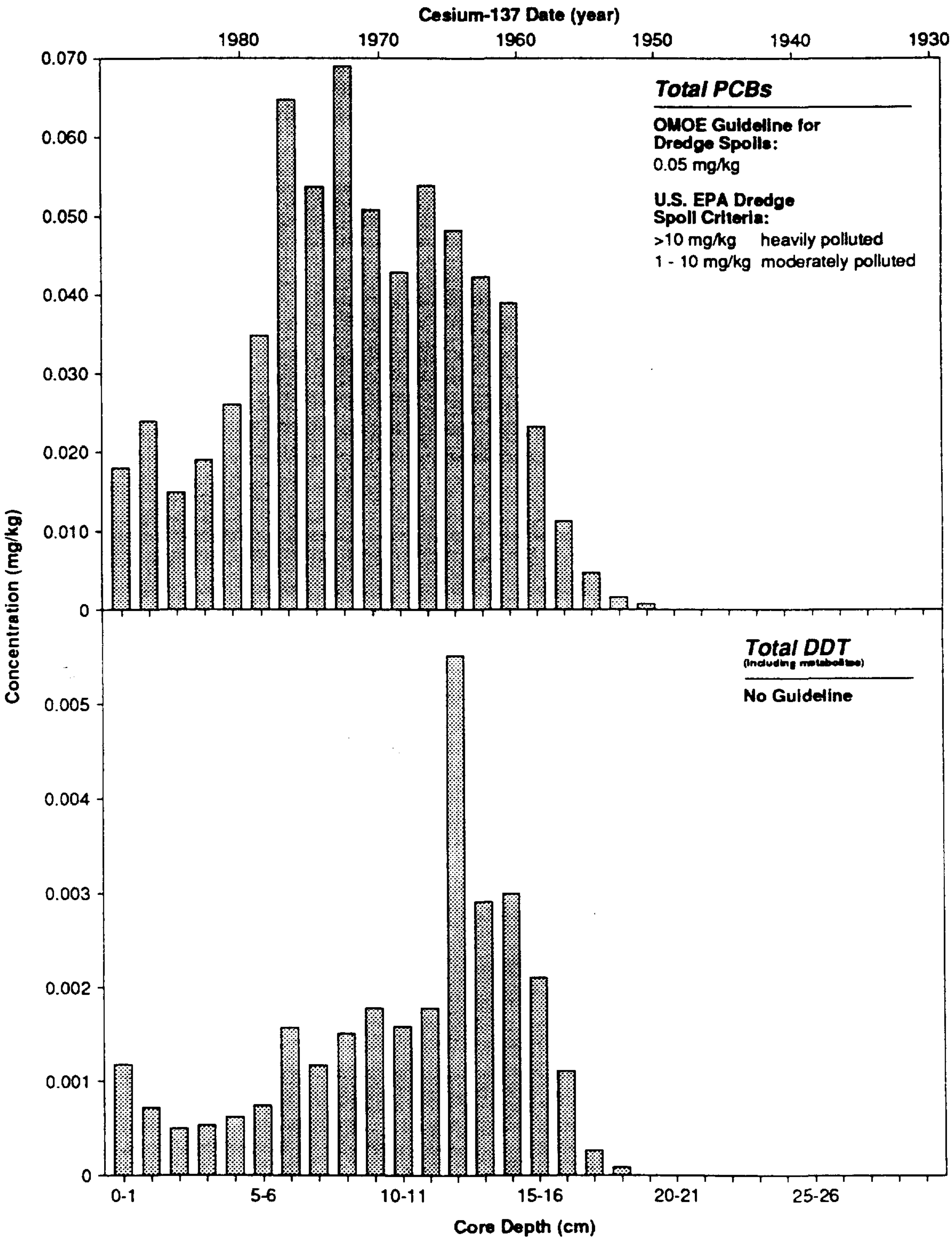
Figure 6.18

St. Marys River Remedial Action Plan

Vertical distribution of total PCBs and DDT in Lake George sediment

Core sample was collected from OMOE site 102 in 1986. Core depths are represented by year sediment was deposited which was determined by Cesium-137 dating.

(from Hesselberg and Hamdy 1987)



Concentrations of total PAHs and in particular, benzo(a)pyrene in the core sample taken from Lake George are shown in Figure 6.19. PAH levels were three orders of magnitude higher than those found for PCBs and DDT (Figure 6.18), thus indicating major PAH sources in the area. Some of the possible sources of PAHs include the combustion of fossil fuels (i.e. the burning of wood, coal and automobile exhaust), fossil fuel spills (i.e. coal or petroleum, used crankcase oil), and the production of asphalt, coke, coal tar pitch, carbon black and creosote (Kauss and Hamdy 1991).

The core profile indicates that PAH inputs to the river increased substantially in the early 1940's, probably due to increased steel production during World War II. A small lag occurred in the late 1940's to early 1950's, followed by a sharp increase in the late 1950's, with peaks during the late 1960's and early 1970's. The pattern of total PAH and benzo(a)pyrene concentrations in the sediments of Lake George track historical trends in steel production and coking processes at the Algoma Steel Mill in Sault Ste. Marie, Ontario (Hesselberg and Hamdy 1987).

Considerably lower PAH concentrations occur in more recent sediments, probably due to a combination of lower steel production, improved pollution control systems and increased river flow along the Ontario shore (Hesselberg and Hamdy 1987).

Changes in the relative distribution of the different PAHs at three core depths are shown in Figure 6.20. Sediments 29 cm to 30 cm deep represent materials deposited about 1930, before significant industrialization of the area. The major PAHs were indeno(1,2,3-cd)pyrene and benzo(g,h,i)perylene. Benzo(a)pyrene was the dominant PAH at a depth of 11 to 12 cm (about 1968) however, other 4- and 5-ringed PAHs including pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene and benzo(k)fluoranthene were also present at high concentrations relative to other PAHs (Figure 6.20). These PAHs with the higher molecular weight (4- and 5-ringed) are generally produced by high-temperature combustion of fossil fuels and may be by-products of the coking process (Kauss and Hamdy 1991).

In recent surficial sediments (0–1 cm depth), naphthalene and phenanthrene represent a more significant fraction of the total PAHs, together with the 4- and 5-ringed PAHs, although other PAHs are still more abundant than at the other two depths (Figure 6.20). Naphthalene, acenaphthylene, acenaphthene and fluoranthene are lower-weight PAHs and their primary sources may be fossil fuel spills such as coal and petroleum. Concentrations of naphthalene exhibited the greatest increase from 1968 to 1985, but naphthalene is also the most readily degraded or dissolved in water (NRCC 1983). Naphthalene concentrations in older sediments likely were lost more quickly than other PAHs deposited at the same time, thus appearing to be less abundant. However, concentrations of all the lower weight PAHs are much less than concentrations of the 4- to 5-ringed PAHs in the recent sediments, indicating that high temperature combustion of fossil fuels is still the greatest source of PAHs.

6.2.2.3 Metals

The vertical distributions of vanadium (V), nickel (Ni), copper (Cu) and cobalt (Co) in the Lake George sediment core were relatively uniform with depth (Figure 6.21). Concentrations were relatively constant, averaging about 60 mg/kg V, 43 mg/kg Ni, 35 mg/kg Cu and 18 mg/kg Co. This would indicate that either the sources of these elements had not changed significantly from 1950 to 1986, or that these concentrations represent natural background levels and there are no significant sources of these elements to Lake George and the St. Marys River.

The vertical distributions of zinc, lead and chromium in the sediment core exhibited peak levels over time (Figure 6.22). Zinc concentrations increased gradually from 139 mg/kg to 410 mg/kg from 20 cm (approx. 1950) to 12 cm (approx. 1969), and then decreased to 185 mg/kg at 4 cm of depth (approx. 1984). Lead peaked at 94 mg/kg at 11 cm (approx. 1970). Chromium peaked at 189 mg/kg at 16 cm (approx. 1960). Concentrations of all three elements peaked in the 1960's and 1970's and have since declined, indicating that

Figure 6.19

St. Marys River Remedial Action Plan

Vertical distribution of total PAHs and benzo(a)pyrene in Lake George sediment

Core sample was collected from OMOE site 102 in 1986. Core depths are represented by year sediment was deposited which was determined by Cesium-137 dating.

(from Hesselberg and Hamdy 1987)

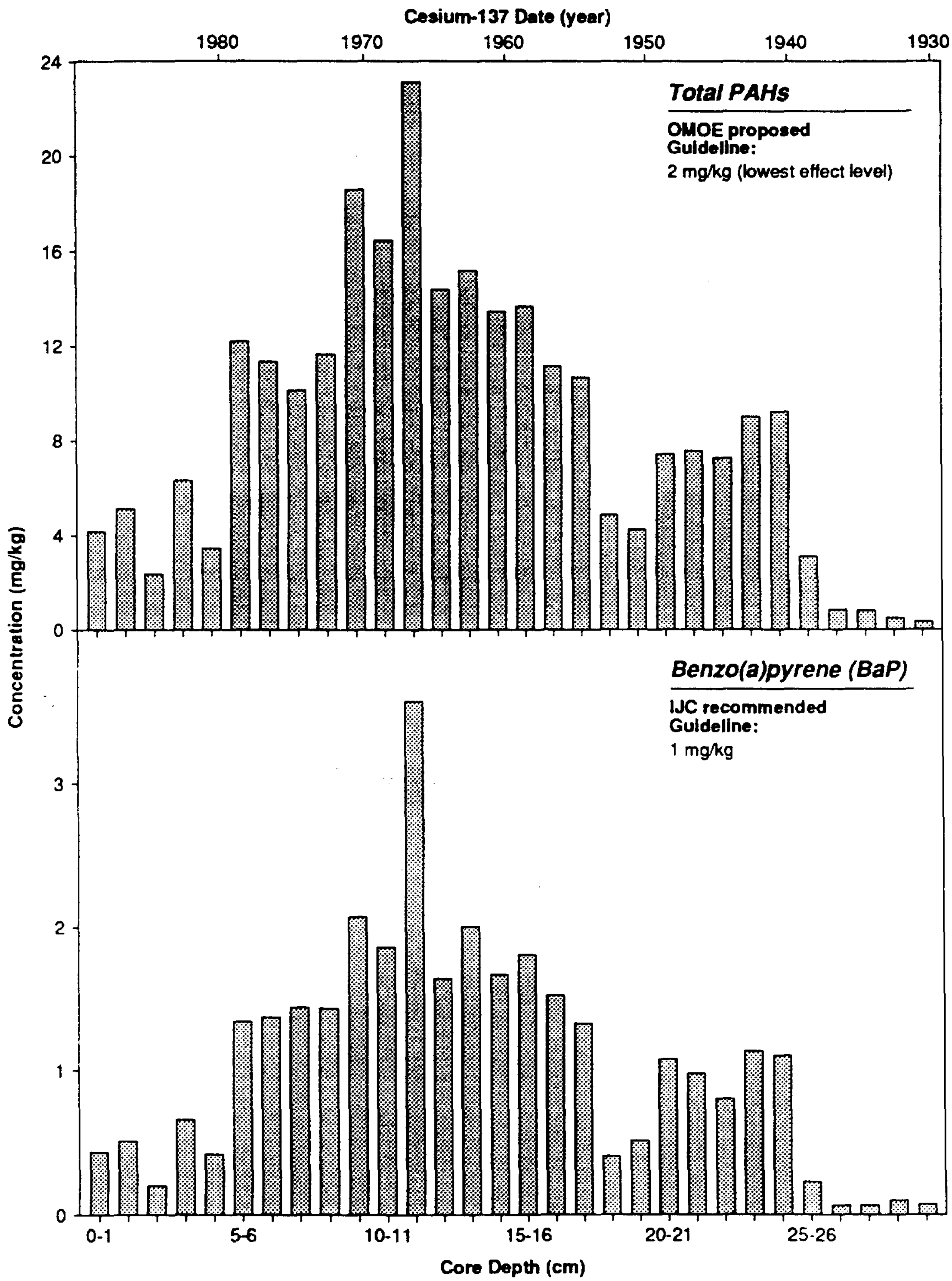


Figure 6.20

St. Marys River Remedial Action Plan

Concentration of different PAHs at selected depths of a Lake George sediment core

Core sample was collected from OMOE site 102 in 1986. Core depths are represented by year sediment was deposited which was determined by Cesium-137 dating.

(from Hesselberg and Hamdy 1987)

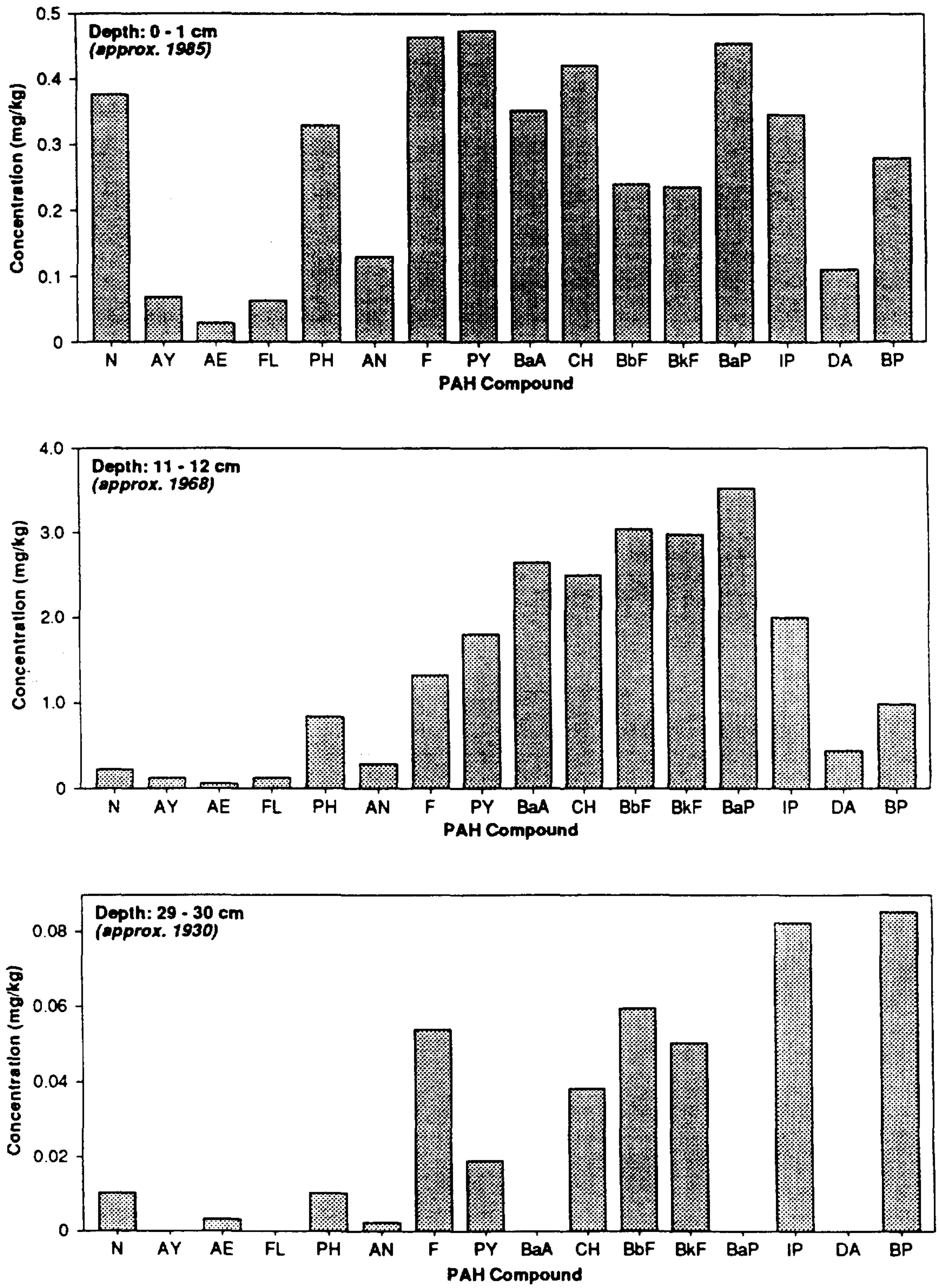


Figure 6.21

St. Marys River Remedial Action Plan

Vertical distributions of vanadium, nickel, copper and cobalt in Lake George sediment

Core sample was collected from OMOE site 102 in 1986. Core depths are represented by year sediment was deposited which was determined by Cesium-137 dating.

(prepared from UGLCCS 1988)

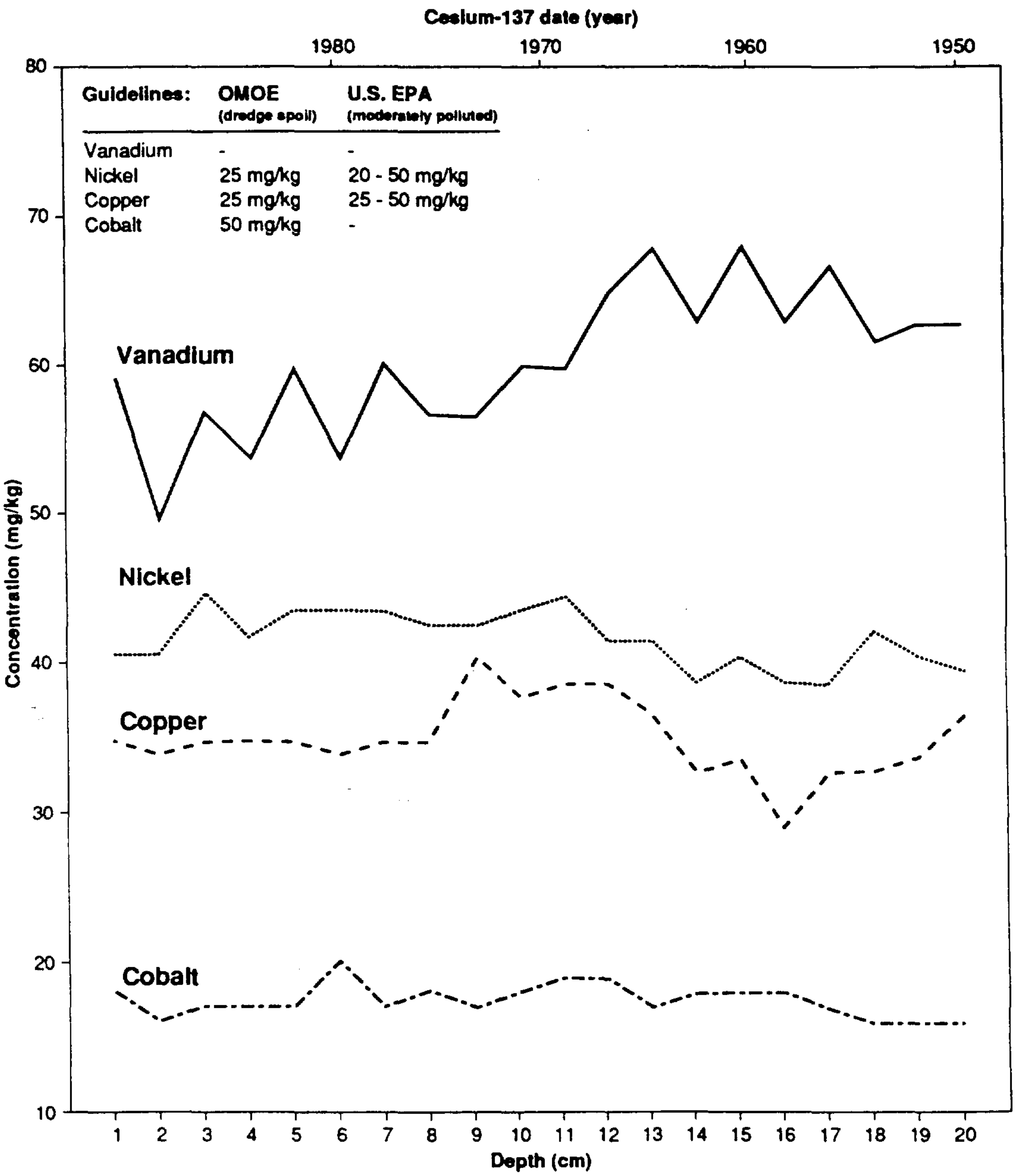


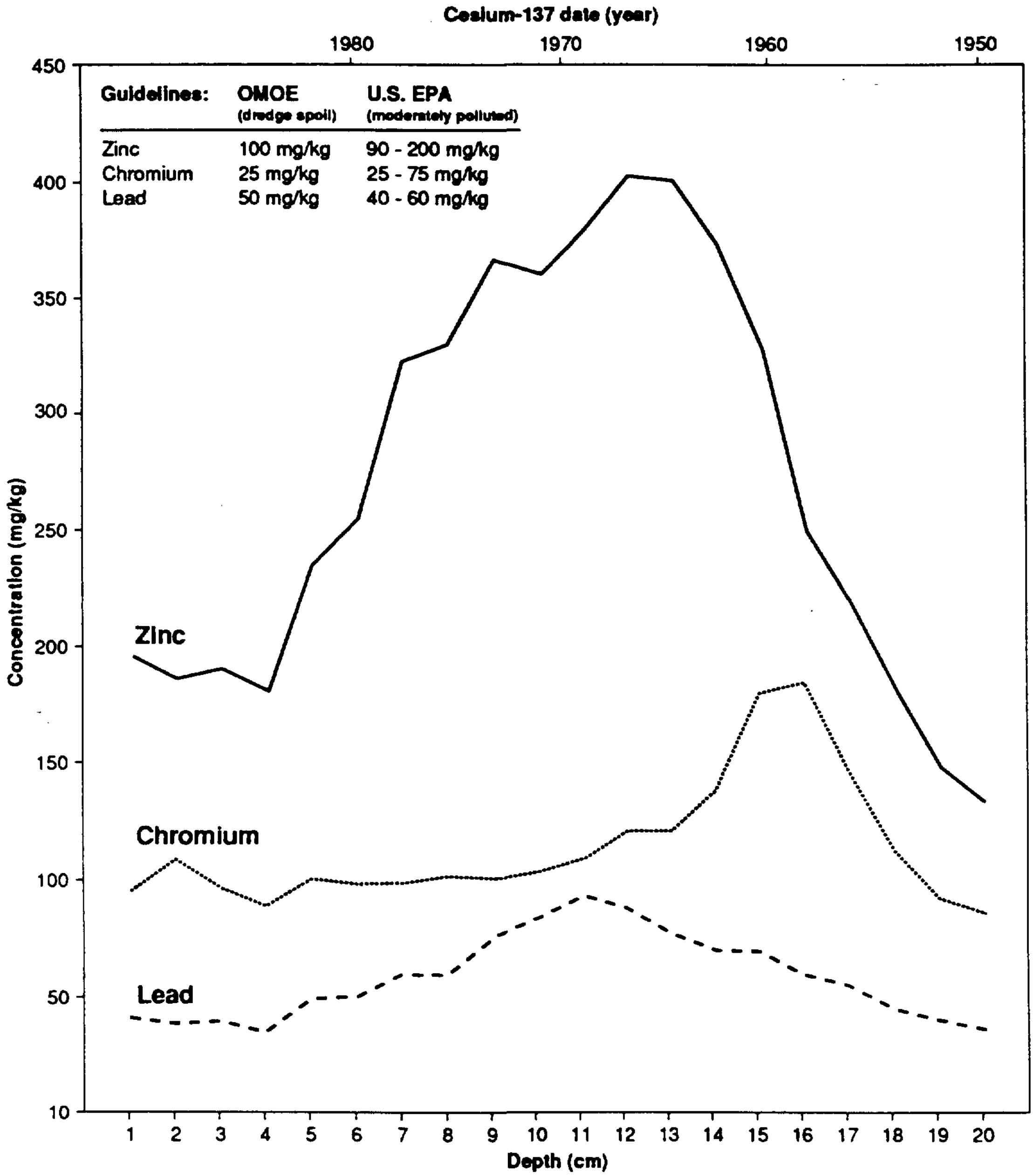
Figure 6.22

St. Marys River Remedial Action Plan

Vertical distributions of zinc, chromium and lead in Lake George sediment

Core sample was collected from OMOE site 102 in 1986. Core depths are represented by year sediment was deposited which was determined by Cesium-137 dating.

(prepared from UGLCCS 1988)



loadings of these elements to Lake George and the St. Marys River have decreased. It should be noted that Algoma Steel operated a chromium smelter in the vicinity of the Terminal Basins outfall. This smelter was closed in 1952 and may have acted as a source of chromium to the St. Marys River.

An average sedimentation rate of 0.6 cm/year indicates that approximately 2.4 cm at the top of the core, has been influenced by the 1982 increase in flow along the Ontario shore from the hydroelectric facility. This increase in flow may have affected the sediment distribution, sedimentation rate and is likely a factor resulting in slight increases or decreases of contaminant levels in Lake George sediment. Figure 6.22 shows that zinc values increase slightly from 3 to 1 cm, chromium levels decrease slightly and lead values remain relatively constant.

6.2.2.4 Oil and Grease

The distribution of oil and grease in the Lake George sediment core differed from that of total PAHs and zinc (Figure 6.23). Oil and grease levels increased steadily between the 1930's (360 mg/kg) and the late 1970's (3,580 mg/kg). The highest level (8,190 mg/kg) occurred in the mid-1970's indicating that loadings of oil and grease have declined in recent years. Oil and grease levels decrease in the top 3 cm (Figure 23). Increased flows along the Ontario shore since 1982 may be one factor affecting the deposition of sediment and hence oil and grease in Lake George.

6.2.3 Surficial Sediment Contamination

Numerous surficial sediment surveys of the St. Marys River have been conducted by both Ontario and Michigan since 1968. These surveys identified existing contaminants and their sources and determined the extent and degree of contamination within the river sediments. Sediment surveys were carried out by OMOE in 1968 (Veal 1968), in 1973 (Hamdy *et al.*, 1978), in 1983 (Kauss 1986),in 1985 (Hesselberg and Hamdy 1987) and in 1987 and 1989 (results not yet available). United States agencies conducting sediment surveys were the U.S.ACOE in 1970, 1972 and 1982, MDNR in 1978 and the U.S.EPA and U.S.FWS in 1984/1985 (Hesselberg and Hamdy 1987).

The most extensive sediment surveys, carried out by OMOE and U.S.EPA/FWS in 1985, covered the entire St. Marys River AoC. OMOE collected sediment samples at 71 stations (Figure 6.16) and U.S.EPA/FWS collected samples at 125 stations (Figure 6.24). Only the top 3 cm were sampled for these surveys. Results from both these surveys are in Appendix 6.2.

In order to compare contaminant levels in sediments, and determine their spatial distribution, the St. Marys River RAP team defined an arbitrary set of criteria outlined in Table 6.6. This "RAP Sediment Criteria" for the classification of St. Marys River surficial sediment was defined using a combination of the U.S. EPA Guidelines for Pollution Classification of Great Lakes Harbor Sediments and OMOE Open Water Disposal Guidelines for Dredge Spoils. The "RAP Sediment Criteria" delimits non-polluted, moderately polluted or heavily polluted concentration ranges (Table 6.6). Figures showing the spatial distribution of contaminants were prepared by MDNR using the "RAP Sediment Criteria". Data used in the preparation of these figures were the 1984/1985 OMOE, U.S.EPA and U.S.FWS (Hesselberg and Hamdy 1987), MDNR data collected in June, 1978 and the U.S.ACOE sediment data collected in 1970, 1972 and 1982.

Results from the 1985 OMOE and 1984/1985 U.S. EPA/FWS are then compared to the lowest criterion from the OMOE Open Water Disposal Guidelines (OWDG) and U.S. EPA Sediment Classification Guidelines (Tables 6.7 and 6.8). These guidelines only provide a comparison of relative concentrations and are not based on biological effects (UGLCCS 1988). The new draft OMOE sediment quality guidelines take into account biological effects, however they are only in draft version and were not available for the preparation of this report (see Appendix 6.3 for the draft guidelines).

Figure 6.23

St. Marys River Remedial Action Plan

Vertical distribution of oil and grease in Lake George sediment

Core sample was collected from OMOE site 102 in 1986. Core depths are represented by year sediment was deposited which was determined by Cesium-137 dating.

(from UGLCCS 1988)

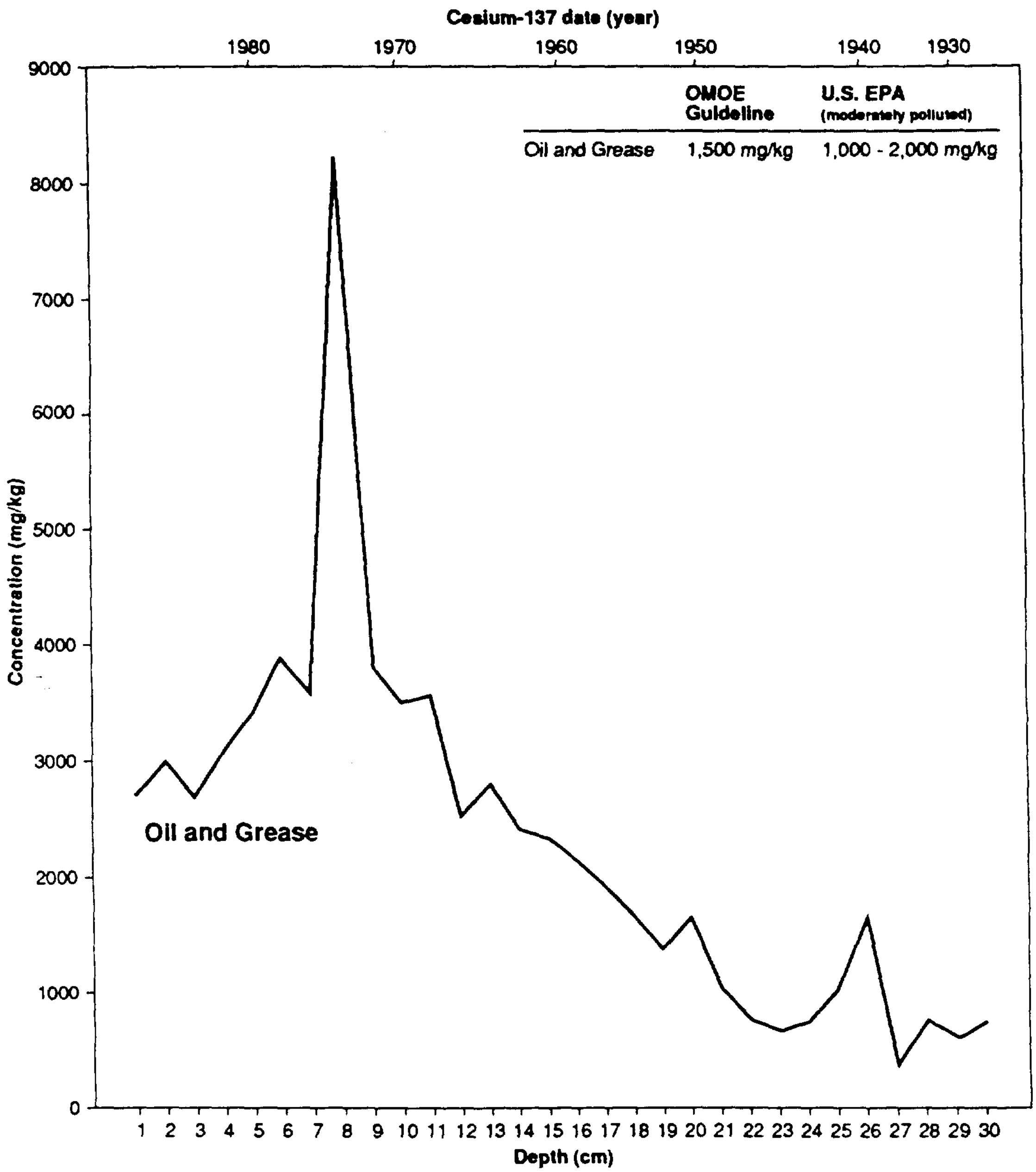
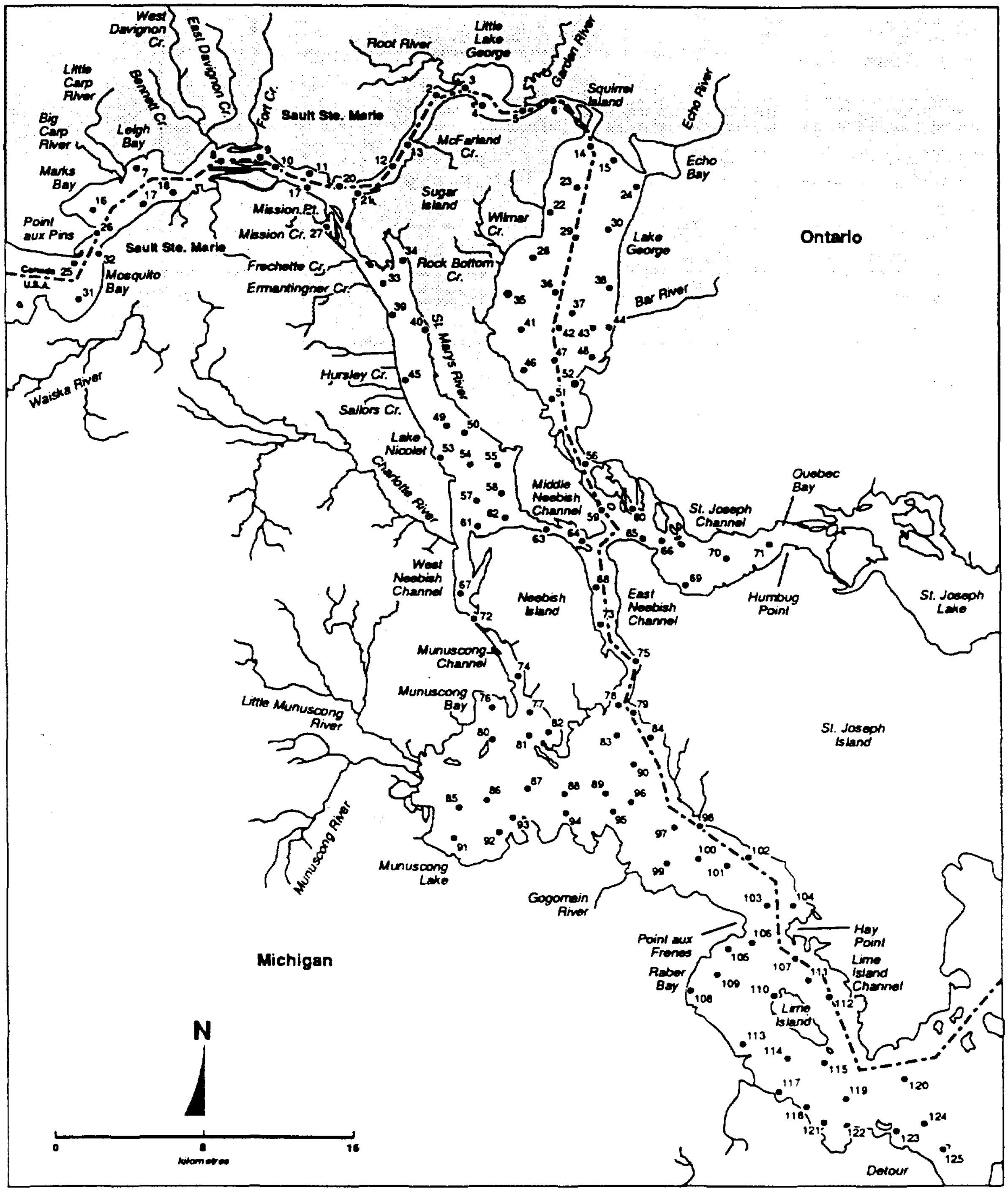


Figure 6.24

St. Marys River Remedial Action Plan

Location of U.S. EPA and U.S. FWS 1985 sediment sampling sites

(from Hesselberg and Hamdy 1987)



• sampling site

Table 6.6 "RAP Sediment Criteria" used for the classification of St. Marys River surficial sediments. (Criteria were developed from OMOE Open Water Disposal Guidelines for Dredged Material and U.S. EPA Guidelines for the Pollution Classification of Great Lakes Harbor Sediments).

Parameter	"RAP Sediment Criteria" (mg/kg)		
	Non Polluted	Moderately Polluted	Heavily Polluted
Total Phosphorus	<420	420 - 650	>650
Total Kjeldahl Nitrogen	<1000	1000 - 2000	>2000
Ammonia	<75	75 - 200	>200
Oil and Grease	≤1000	1000 - 2000	>2000
Arsenic	<3	3 - 8	>8
Cadmium	<1	1 - 6	>6
Chromium	<25	25 - 75	>75
Copper	<25	25 - 50	>50
Cyanide	<0.1	0.1 - 0.25	>0.25
Iron	<17,000	17,000 - 25,000	>25,000
Lead	<40	40 - 60	>60
Manganese	<300	300 - 500	>500
Mercury	<0.3	0.3 - .9	>1
Nickel	<20	20 - 50	>50
PCBs	<0.05	0.05 - 9.99	>10
Zinc	<90	90 - 200	>200

Table 6.7 Percent of sediment samples collected from the St. Marys River during 1984 and 1985 by U.S.EPA, U.S.FWS, or OMOE that exceeded the moderately polluted U.S.EPA and/or OMOE sediment pollution guidelines given in mg/kg, except where noted (Hesselberg and Hamdy 1987).

Sources of Samples	Total Samples	Oil and Grease	Percent Loss on Ignition	P	TKN	Cyanide	PCBs	As	Cd	Cr	Cu	Fe%	Pb	Hg	Ni	Zn
% Exceeding U.S.EPA Moderately Polluted Guidelines																
U.S. EPA Guidelines		**1000**	**5**	**420**	**1000**	**0.1**	**1***	**3**	**<6***	**25**	**25**	**1.7**	**40**	**1**	**20**	**90**
Survey:																
U.S.EPA 1984	19	5	5	63	10	100	0	0	0	44	22	32	0	0	32	0
U.S.EPA/FWS 1985	125	17	18	NA	NA	78	1	NA	0	56	34	NA	11	0	34	18
OMOE 1985	71	42	28	45	35	NA	0	58	0	58	49	44	34	0	21	49
% Exceeding OMOE Guidelines																
OMOE Guidelines		**1500**	**6**	**1000**	**2000**	**0.1**	**0.05**	**8**	**1**	**25**	**25**	**1**	**50**	**0.3**	**25**	**100**
Survey:																
U.S.EPA 1984	19	0	5	0	0	100	0	0	0	44	22	47	0	0	32	0
U.S.EPA/FWS 1985	125	10	12	NA	NA	78	27	NA	4	56	34	NA	9	1	19	17
OMOE 1985	71	38	21	0	13	NA	14	31	3	58	49	66	23	1	6	46

NA - Not analyzed or not available
* Heavily polluted

Table 6.8 Summary of metals in surficial sediment by area with range and percentage of samples exceeding the lesser of the U.S. EPA moderately polluted or OMOE sediment pollution Guidelines. (prepared from Hesselberg and Hamdy 1987). All concentrations are in mg/kg.

Area Location	Agency	No. Samp.	As	Cd	Cr	Cu	Fe	Pb	Hg	Ni	Zn
U.S.EPA Moderately Polluted Guideline:			3	<6*	25	25	17,000	40	1	20	90
OMOE sediment pollution Guidelines:			8	1	25	25	10,000	50	0.3	25	100
Algoma Steel SSM	US EPA/FWS	8	NA	13% 0.4-1.1	75% 10-78	63% 18-49	NA	63% 18-72	0% 0.00-0.11	13% 6-22	63% 36-330
	OMOE	9	89% 2.97-43.90	0% 0.20-0.20	89% 12-75	56% 4.8-52	100% 11,000-150,000	44% 8.2-250	0% 0.01-0.16	22% 7-35	67% 32-660
Little Lake George	US EPA/FWS	4	NA	50% 0.2-1.8	50% 7-58	50% 7-110	NA	50% 7-130	0% 0.01-0.19	50% 4-30	50% 29-470
	OMOE	5	100% 4.14-10.21	20% 0.50-1.10	100% 40-61	100% 32-69	100% 19,000-39,000	60% 27-54	0% 0.08-0.19	20% 14-23	100% 120-220
Lake George	US EPA/FWS	24	NA	0% 0.2-0.7	33% 0-56	29% 4-53	NA	21% 7-76	0% 0.00-0.11	25% 2-31	29% 16-240
	OMOE	22	68% 1.96-14.82	5% 0.20-1.10	68% 11-55	82% 7.3-59	91% 8,600-42,000	36% 3.8-68	0% 0.01-0.21	32% 3.6-25	50% 21-260
Lake Nicolet	US EPA/FWS	15	NA	7% 0.2-1.2	20% 5-45	7% 4-41	NA	7% 7-43	0% 0.00-0.27	7% 2-25	7% 11-140
	OMOE	7	29% 1.35-4.92	0% 0.20-0.20	29% 9.3-49	14% 6.2-39	29% 5,500-21,000	0% 2.8-29	0% 0.01-0.06	14% 2.0-21	14% 14-110
Lake Munuscong	US EPA/FWS	30	NA	0% 0.2-0.4	80% 16-70	40% 8-41	NA	0% 7-28	3% 0.00-0.31	47% 5-44	0% 20-74
	OMOE	0	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lime Island Channel	US EPA/FWS	21	NA	0% 0.2-0.3	81% 4-68	52% 2-42	NA	0% 7-38	0% 0.00-0.12	71% 3-38	19% 6-110
	OMOE	0	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA Not Available
* Heavily polluted

Table 6.7 shows the percent of samples from the 1985 OMOE survey and 1984/1985 U.S. EPA/FWS survey that exceeded the actual U.S. EPA moderately polluted or OMOE Open Water Disposal Guidelines. Tables 6.8 and 6.9 show the percent exceedences and range of values by area in the St. Marys River. The percents were calculated by using the lowest guideline for each contaminant. 1984 data was not used in Tables 6.8 and 6.9 because there were insufficient samples for each location. The U.S. EPA/FWS samples gives the best picture of overall river pollution because of the even distribution of sampling sites. OMOE samples locations were biased toward areas of known contamination (Hesselberg and Hamdy 1987).

6.2.3.1 Iron

The 1985 OMOE and U.S.EPA/FWS surveys showed iron concentrations were elevated in several depositional zones throughout the St. Marys River. Figure 6.25 shows sediments heavily polluted with iron occur from the Algoma Slip downstream along the Ontario shoreline, the northwest shore of Sugar Island and in the centre of Little Lake George and Lake George. Table 6.8 shows that all OMOE samples taken downstream of Algoma Steel at Sault Ste. Marie and Little Lake George exceeded the OMOE and U.S.EPA guidelines. Values ranged from 11,000 to 150,000 mg/kg and 19,000 to 39,000 mg/kg respectively. 91% of the OMOE samples taken in Lake George exceeded the guidelines. Samples collected in lower Lake Nicolet and Munuscong Lake were not analyzed for iron, thus its spatial distribution in these areas is not known.

6.2.3.2 Chromium

The 1985 sediment surveys show that most sediments throughout the St. Marys River AoC are moderately contaminated according to the U.S. EPA dredge spoil guideline (25-75 mg/kg). Values throughout the river ranged from 0 to 78 mg/kg (Table 6.8 and Figure 6.26). The highest values were found downstream of Algoma Steel along the Ontario shore (10-78 mg/kg) and in Lake Munuscong (16-70 mg.kg). Earlier USACOE and MDNR surveys showed that sediments along the Michigan shore near the Cannelton Industries site and those along the Ontario shore just downstream of the locks are heavily polluted with chromium (Figure 6.26) (Kenaga 1979, sampled in 1978 by MDNR). 1978 chromium concentrations in bottom sediments ranged from 8 to 10 mg/kg at uncontaminated sites and from 20 to 2,200 mg/kg nearshore and downstream of the Cannelton site. Concentrations in sediments immediately adjacent to the site were as high as 4,000 mg/kg (Kenaga 1979). Studies by Kenaga (1979) have shown the Cannelton Industries site to be a source of chromium to the St. Marys River. The 1991 U.S. EPA Remedial Investigation showed that concentrations of chromium in sediment upstream of the Cannelton site ranged from 3.65 to 16.25 mg/kg. The highest concentrations of chromium were found downstream of the site in a small bay called "Tannery Bay" where values reached 31,000 mg/kg (U.S.EPA 1991).

Background data for chromium in sediments can be determined from one core sample taken by OMOE in 1987 in Marks Bay. The average of all chromium values from the core was 22.9 mg/kg with a range of 15-30 mg/kg (OMOE unpublished 1987 data). This would indicate that background chromium values in surficial sediment are relatively high and maximum values exceed the OMOE and U.S. EPA dredge spoil criteria (25 mg/kg).

6.2.3.3 Zinc and Lead

OMOE 1973 and 1983 surveys have shown that maximum concentrations of zinc in surficial sediments occurred within the vicinity of the Algoma Slip and along the Ontario shore downstream of the Rapids. Figure 6.27 shows that maximum concentrations have decreased from 1973 (1100 mg/kg) to 1983 (654 mg/kg). This reduction is due to a reduction in zinc loadings from Algoma Steel discharges and the doubling of river flow along the Ontario shoreline resulting from increased diversion to the Clerque Generating Station in 1982 (Kauss 1986).

Table 6.9 Summary of non-metal contaminants in surficial sediment by area with range and percentage of samples exceeding the lesser of the U.S. EPA moderately polluted or OMOE sediment pollution Guidelines. (prepared from Hesselberg and Hamdy 1987). All concentrations are in mg/kg unless otherwise noted.

Area	Agency	No. Samp.	Oil and Grease	LOI (%)	Phenol	Cyanide	P	TKN	PCBs
U.S.EPA Moderately Polluted Guideline:			1,000	5	-	0.1	420	1,000	1
OMOE sediment pollution Guidelines:			1,500	6	-	0.1	1,000	2,000	0.05
Algoma Steel SSM	US EPA/FWS	8	38% 0-5,420	38% DNP	- 0.0-0.5	88% ND-1.6	NA	NA	25% 0.000-0.099
	OMOE	9	44% 185-4,722	44% 0.2-17.4	-	NA	33% 180-760	0% ND-200	11% ND-0.060
Little Lake George	US EPA/FWS	4	50% 360-9,320	50% DNP	- 0.1-11.0	75% ND-2.7	NA	NA	75% 0.025-0.362
	OMOE	5	100% 2,258-7,665	60% 4.4-9.7	-	NA	80% 380-750	100% 1,500-3,000	20% ND-0.060
Lake George	US EPA/FWS	24	21% 0-5,090	13% DNP	- 0.0-2.4	96% ND-2.0	NA	NA	21% 0.000-0.065
	OMOE	22	45% 156-3,929	32% 0.25-6.4	-	NA	73% 300-870	50% ND-2,100	0% ND-0.040
Lake Nicolet	US EPA/FWS	15	0% 0-949	7% DNP	- 0.0-1.8	93% ND-2.9	NA	NA	33% 0.000-0.101
	OMOE	7	14% 143-1,195	14% 0.73-7.1	-	NA	14% 150-500	14% 300-2,900	0% ND
Lake Munuscong	US EPA/FWS	30	0% 0-951	0% DNP	- 0.0-0.7	57% ND-0.7	NA	NA	40% 0.029-0.145
	OMOE	0	NA	NA	NA	NA	NA	NA	NA
Lime Island Channel	US EPA/FWS	21	19% 0-1,250	0% DNP	- 0.0-0.8	81% ND-2.5	NA	NA	5% 0.024-0.052
	OMOE	0	NA	NA	NA	NA	NA	NA	NA

LOI Loss on Ignition
P Total phosphorus
TKN Total kjeldahl nitrogen
DNP Data not provided in Hesselberg and Hamdy (1987) report
NA Not Available
ND Not Detected
* Heavily polluted

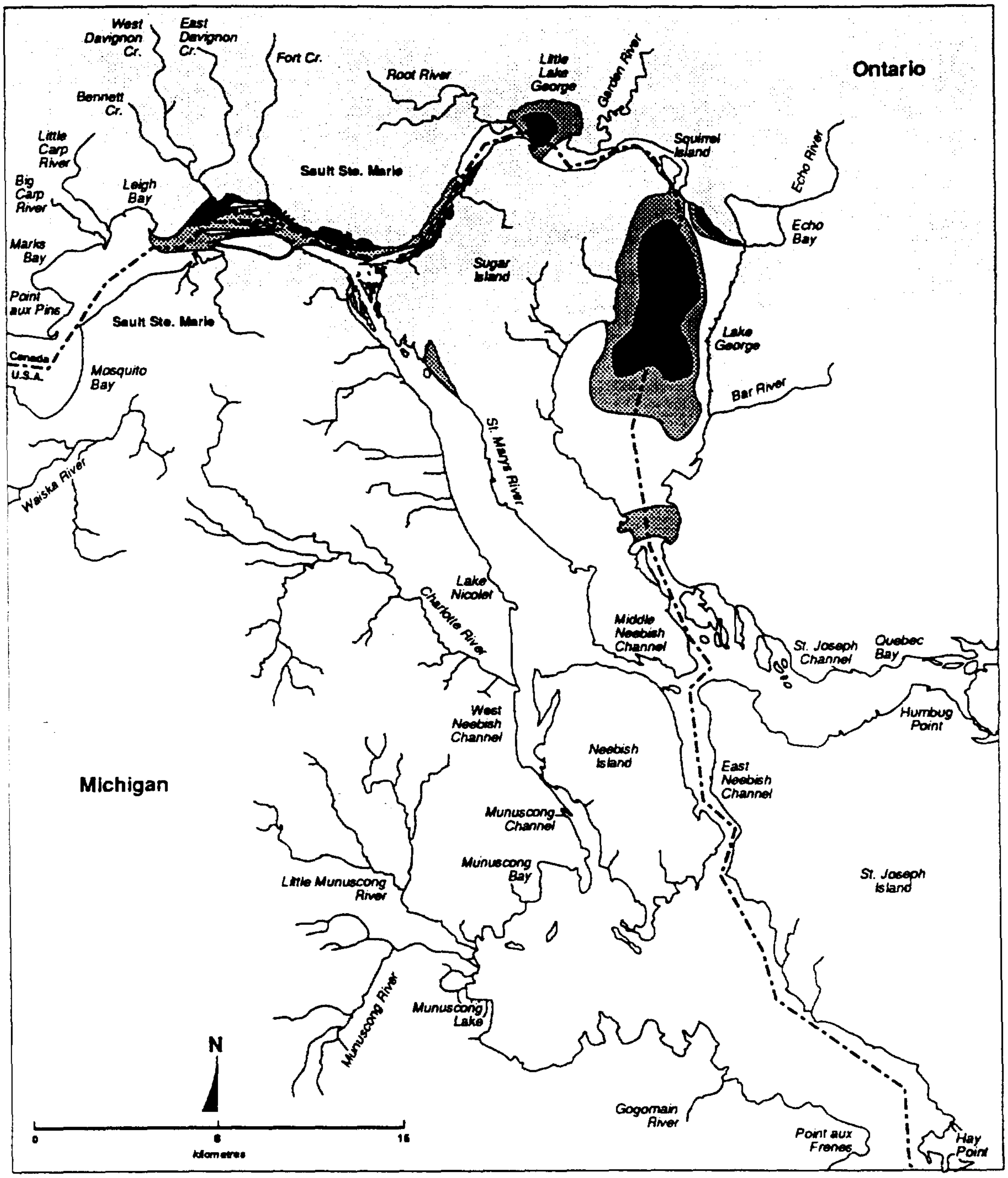
Figure 6.25

St. Marys River Remedial Action Plan

Spatial distribution of iron contamination in surficial sediment in the St. Marys River, 1985

Sediment classification is based on "RAP Criteria Guidelines" (Table 6.6)

(prepared by MDNR from OMOE - U.S. EPA/FWS data collected in 1985 (Appendix 6.2) and USACOE (1970, 1972, 1982) and MDNR (1978) unpublished data)



"RAP Sediment Criteria" for Iron

- non polluted (<17,000 mg/kg)
- moderately polluted (17,000 - 25,000 mg/kg)
- heavily polluted (>25,000 mg/kg)

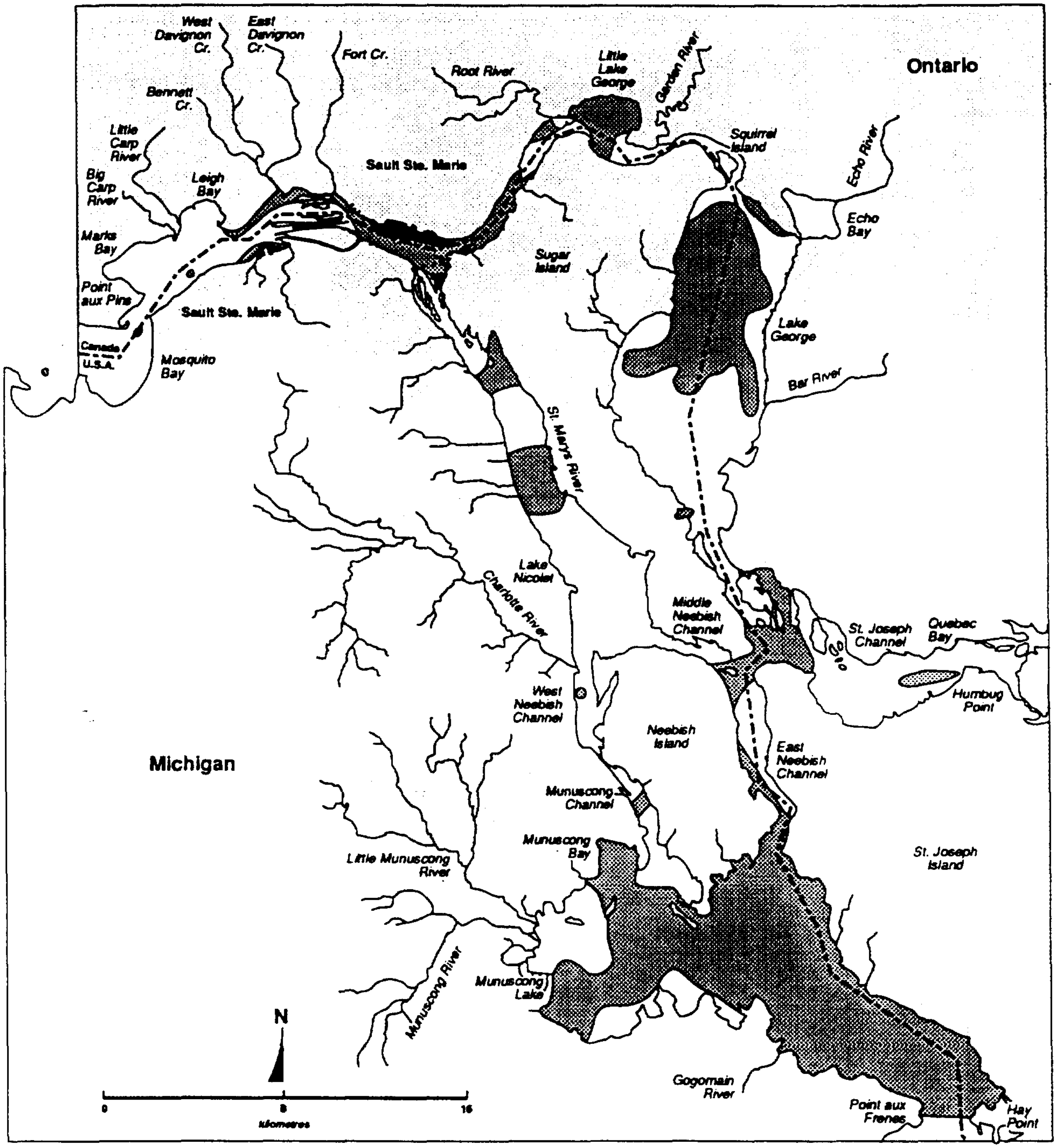
Figure 6.26

St. Marys River Remedial Action Plan

Spatial distribution of chromium contamination in surficial sediment in the St. Marys River, 1985

Sediment classification is based on "RAP Criteria Guidelines" (Table 6.6)

(prepared by MDNR from OMOE - U.S. EPA/FWS data collected in 1985 (Appendix 6.2) and USACOE (1970, 1972, 1982) and MDNR (1978) unpublished data)



"RAP Sediment Criteria" for Chromium

- non polluted (< 25 mg/kg)
- moderately polluted (25 - 75 mg/kg)
- heavily polluted (> 75 mg/kg)

Figure 6.27

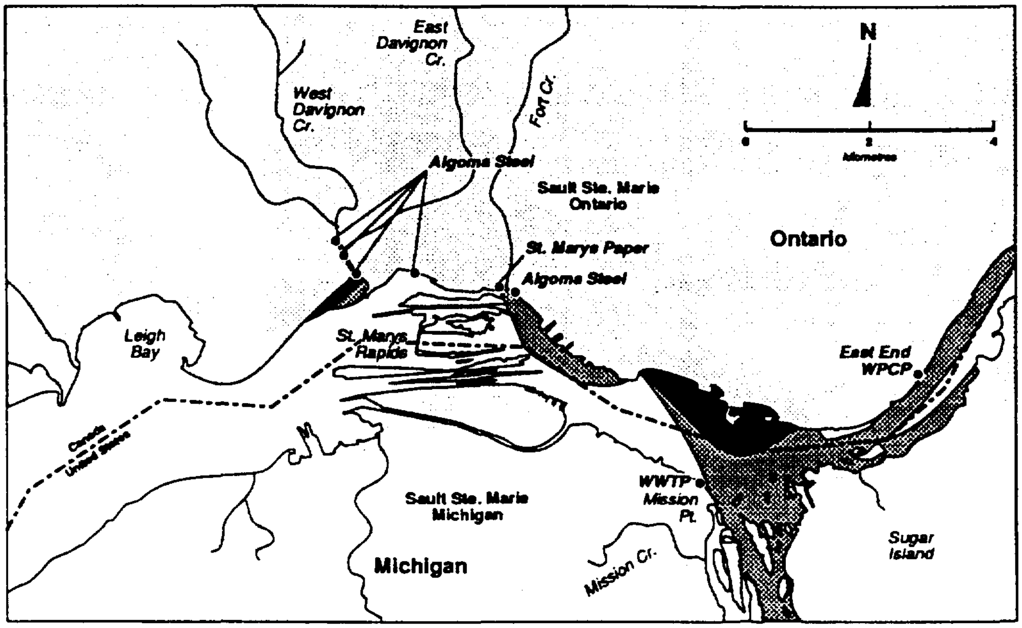
St. Marys River Remedial Action Plan

Spatial distribution of zinc in St. Marys River surficial sediments in 1973 and 1983

The zones and ranges were statistically determined

(Kauss 1988)

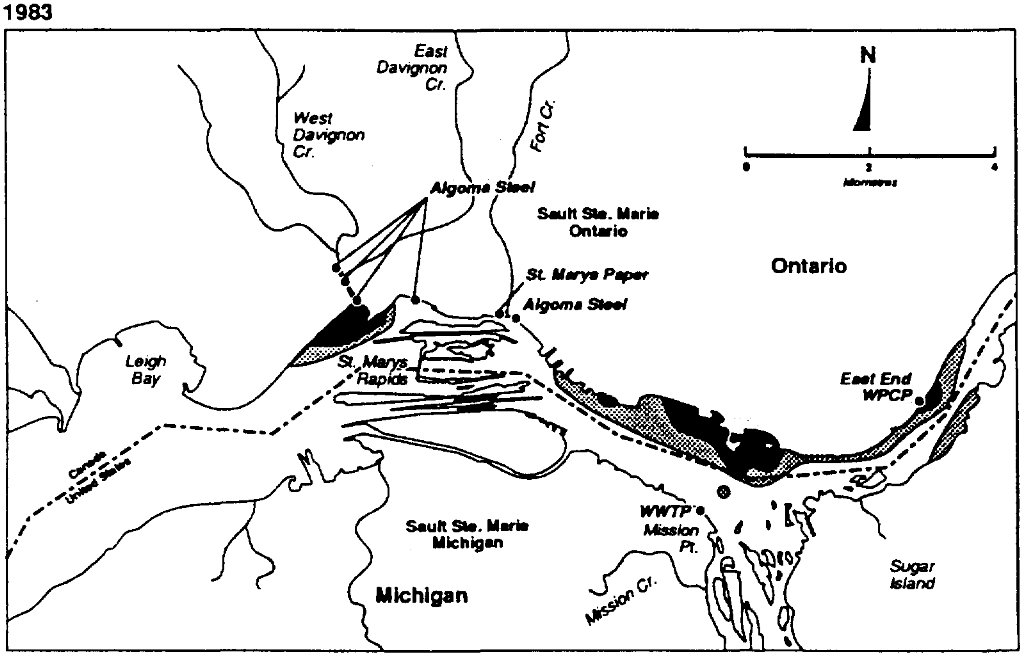
1973



Zone (mg/kg)	Range (mg/kg)
< 60	9.4 - 59
60 - 199	61 - 190
> 199	200 - 1100

• point source discharge location

1983



Zone (mg/kg)	Range (mg/kg)
< 60	7.1 - 58
60 - 199	60 - 160
> 199	200 - 654

• point source discharge location

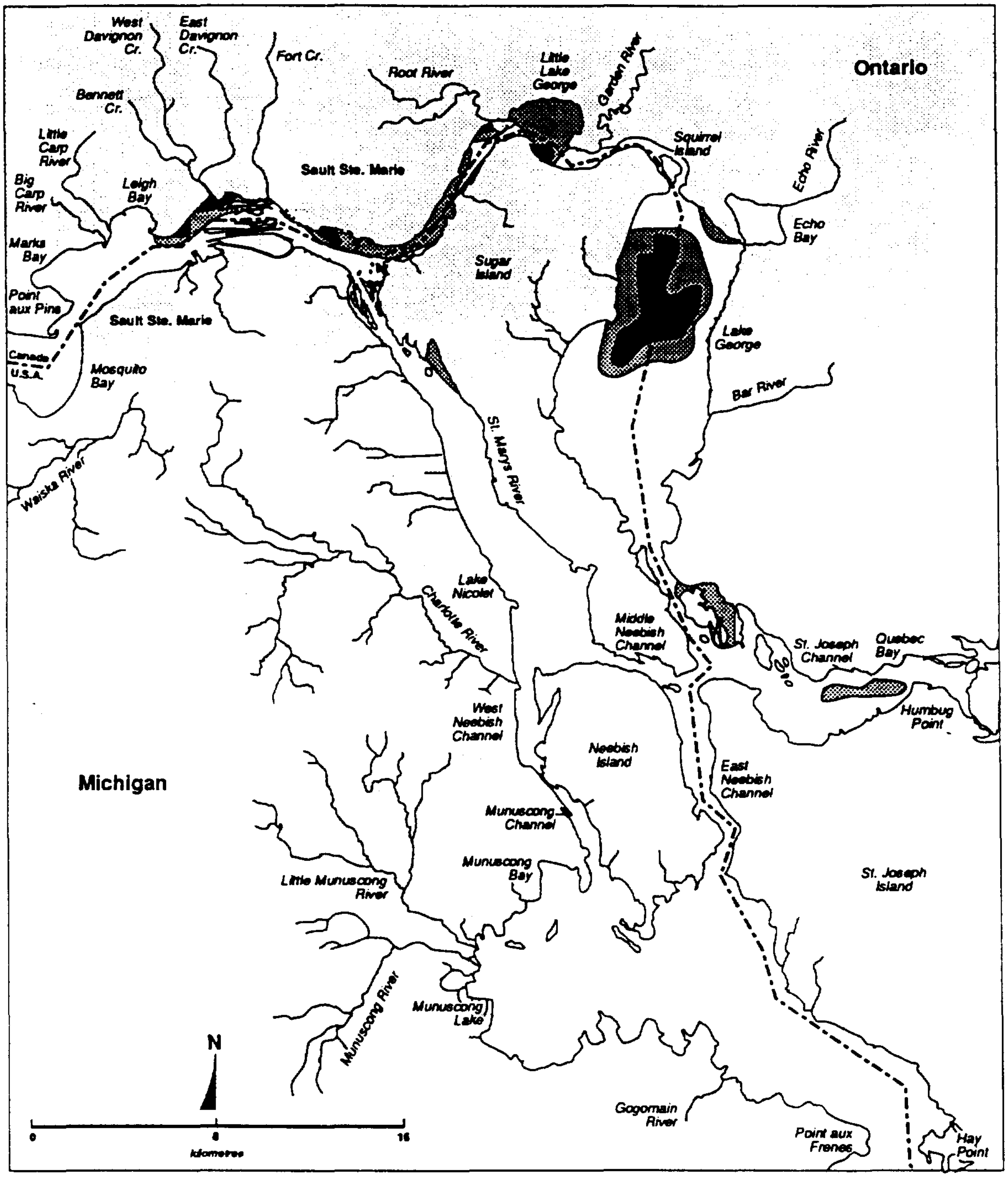
Figure 6.28

St. Marys River Remedial Action Plan

Spatial distribution of zinc contamination in surficial sediment in the St. Marys River, 1985

Sediment classification is based on "RAP Criteria Guidelines" (Table 6.6)

(prepared by MDNR from OMOE - U.S. EPA/FWS data collected in 1985 (Appendix 6.2) and USACOE (1970, 1972, 1982) and MDNR (1978) unpublished data)



"RAP Sediment Criteria" for Zinc

- non polluted (< 90 mg/kg)
- moderately polluted (90 - 200 mg/kg)
- heavily polluted (>200 mg/kg)

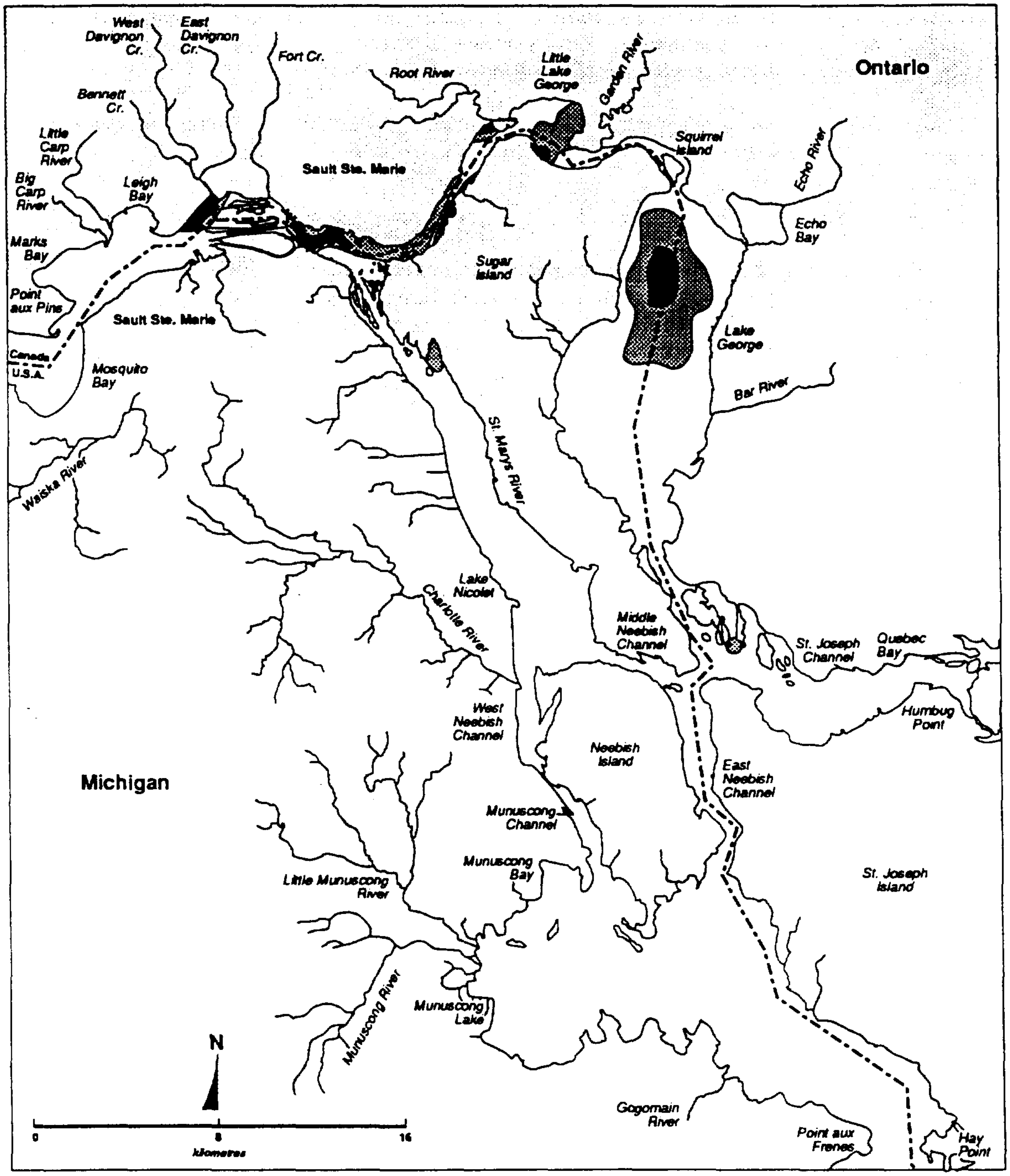
Figure 6.29

St. Marys River Remedial Action Plan

Spatial distribution of lead contamination in surficial sediment in the St. Marys River, 1985

Sediment classification is based on "RAP Criteria Guidelines" (Table 6.6)

(prepared by MDNR from OMOE - U.S. EPA/FWS data collected in 1985 (Appendix 6.2) and USACOE (1970, 1972, 1982) and MDNR (1978) unpublished data)



"RAP Sediment Criteria" for Lead

- non polluted (< 40 mg/kg)
- moderately polluted (40 - 60 mg/kg)
- heavily polluted (> 60 mg/kg)

Results from the 1985 survey showed that sediments heavily polluted with zinc and lead (according to the "RAP Sediment Criteria") were somewhat coincident (Figures 6.28 and 6.29 respectively). These include the Ontario shoreline downstream of Algoma Steel (32-660 mg/kg Zn and 8.2-250 mg/kg Pb), the northwest shore of Sugar Island, in the Lake George Channel opposite Little Lake George (29-470 mg/kg Zn and 7-130 mg/kg Pb) and the centre of Lake George (16-260 mg/kg Zn and 3.8-76 mg/kg Pb) (Table 6.8 and Figures 6.28 and 6.29). Sediments, moderately contaminated with lead and zinc ("RAP Sediment Criteria") occur in Lake Nicolet (11-140 mg/kg Zn and 2.8-43 mg/kg Pb) and the Lime Island Channel (only zinc 6-110 mg/kg). Sediments in Lake Munuscong did not exceed the dredging guidelines and can be regarded as non-polluted with respect to zinc and lead (Table 6.8).

Additionally, sediment heavily polluted ("RAP Sediment Criteria") with lead was found along the Michigan shore immediately downstream of the Sault Edison Electric Co. Canal (Figure 6.29).

6.2.3.4 Arsenic and Manganese

The 1985 survey showed that sediments were moderately to heavily polluted ("RAP Sediment Criteria") with arsenic and manganese in depositional zones along the Ontario shoreline from the Algoma Steel property downstream to Lake George Channel, along the northwest shore of Sugar Island and in the centres of Little Lake George and Lake George (Figures 6.30 and 6.31). Moderately polluted sediments were found in the upper reach of Lake Nicolet. Samples collected in lower Lake Nicolet and Munuscong Lake were not analyzed for arsenic and manganese, thus their spatial distribution in these areas is not known.

Table 6.8 shows samples from the OMOE survey exceeded the U.S. EPA dredge spoil moderately polluted guideline for arsenic (3-8 mg/kg) downstream of Algoma Steel in 89% of the samples (2.97-43.90 mg/kg), in all samples (100%) from Little Lake George (4.14-10.21 mg/kg), in 68% of the samples in Lake George (1.96-14.82 mg/kg) and 7% in upper Lake Nicolet (1.35-4.92 mg/kg).

The U.S. EPA moderately polluted guideline for manganese is 300 to 500 mg/kg. This guideline was exceeded downstream of Algoma Steel in 89% of the samples (1407-3,700 mg/kg), in 80% of the samples from Little Lake George (220-480 mg/kg), in 50% of the samples in Lake George (100-640 mg/kg) and 29% in upper Lake Nicolet (70-7,000 mg/kg).

6.2.3.5 Nickel and Copper

The "RAP Sediment Criteria" identifies sediment heavily polluted with nickel (>50 mg/kg) and copper (>50 mg/kg), occurs along the Ontario shoreline just below the locks (Figures 6.32 and 6.33). In addition, sediments heavily polluted with copper occur in an embayment at the downstream end of Lake George Channel (Figure 6.33). The 1985 survey also showed moderately contaminated sediments in the vicinity of the Algoma Slip, in the depositional zones along the northwest shore of Sugar Island and in Little Lake George, Lake George, Lake Nicolet and Munuscong Lake (Table 6.8 and Figures 6.32 and 6.33).

Data from one core sample, taken by OMOE in 1987 in Marks Bay, show that the average nickel value is 9.2 mg/kg (5.9-13 mg/kg range) and the average copper concentration is 12.2 mg/kg (6.1-39 mg/kg range) (OMOE unpublished 1987 data). This data can be considered as background information. It indicates that the maximum background copper values are high and exceed the OMOE and U.S. EPA dredge spoil criteria (25 mg/kg). The OWDG and U.S. EPA criterion for nickel (25 and 20 mg/kg respectively) in not exceeded by background samples. This suggests that some copper and, to a lesser extent nickel, in the St. Marys River comes from background, however the higher levels of both metals in the river sediment suggest that there are additional sources.

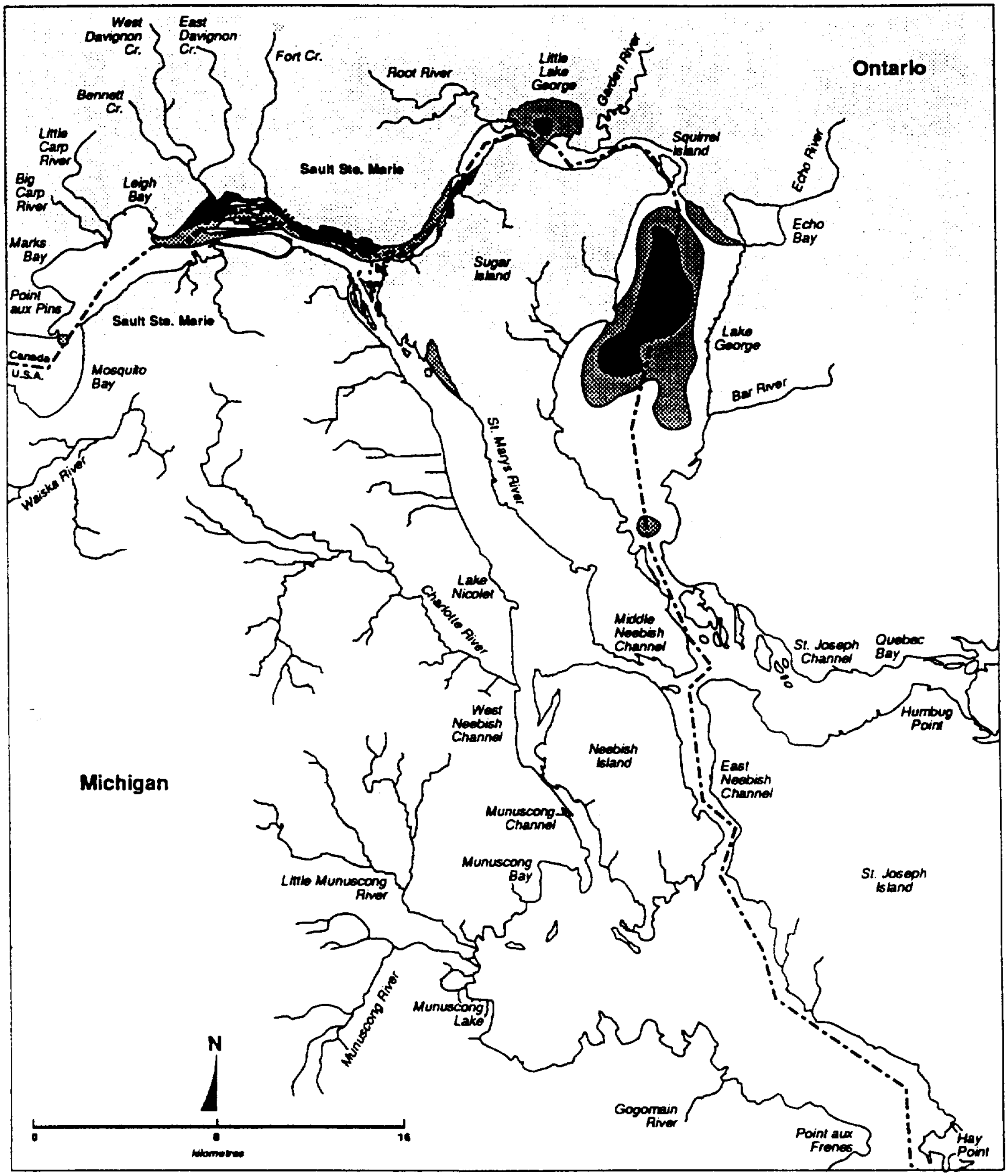
Figure 6.30

St. Marys River Remedial Action Plan

Spatial distribution of arsenic contamination in surficial sediment in the St. Marys River, 1985

Sediment classification is based on "RAP Criteria Guidelines" (Table 6.6)

(prepared by MDNR from OMOE - U.S. EPA/FWS data collected in 1985 (Appendix 6.2) and USACOE (1970, 1972, 1982) and MDNR (1978) unpublished data)



"RAP Sediment Criteria" for Arsenic

- non polluted (< 3 mg/kg)
- moderately polluted (3 - 8 mg/kg)
- heavily polluted (> 8 mg/kg)

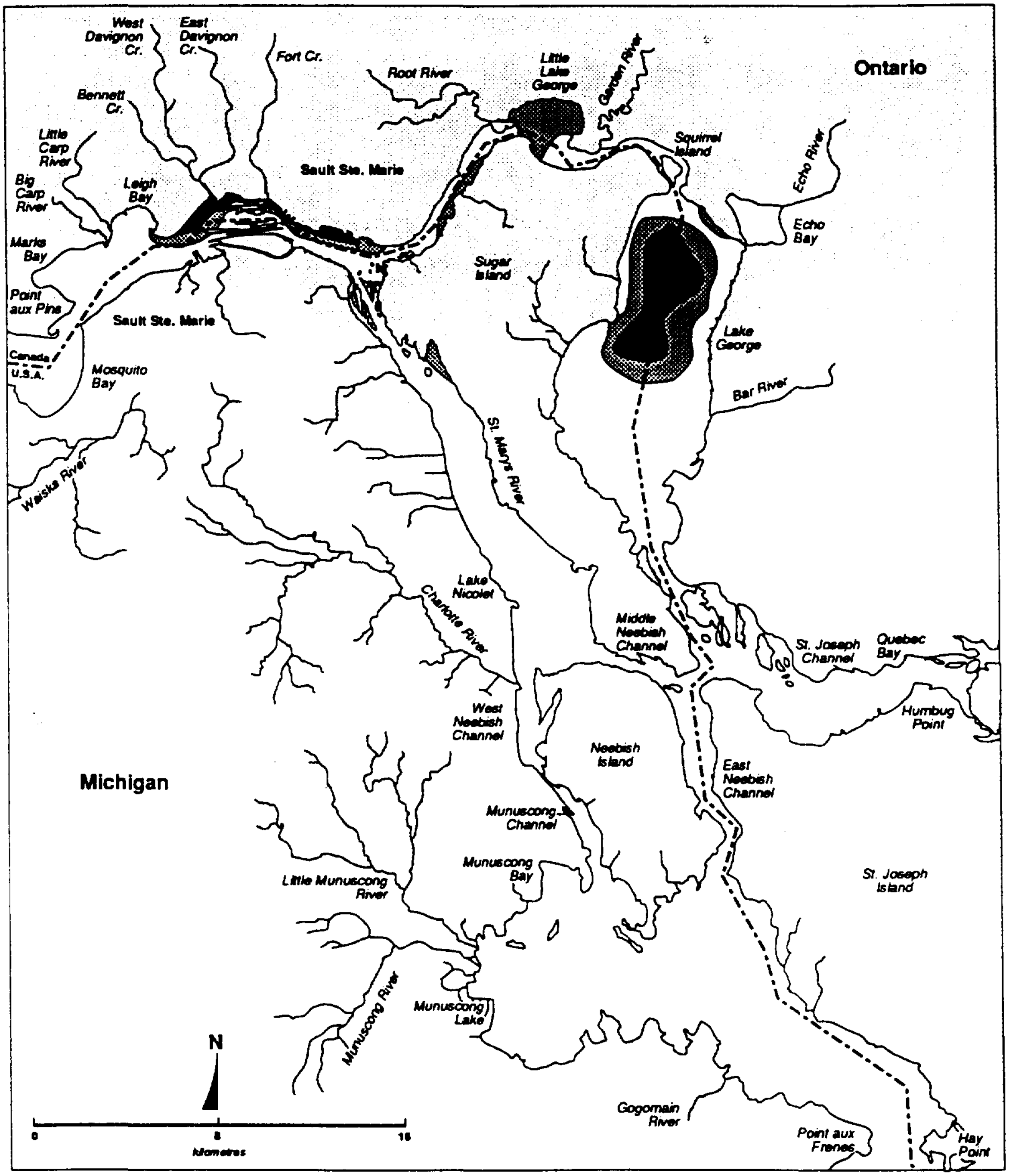
Figure 6.31

St. Marys River Remedial Action Plan

Spatial distribution of manganese contamination in surficial sediment in the St. Marys River, 1985

Sediment classification is based on "RAP Criteria Guidelines" (Table 6.6)

(prepared by MDNR from OMOE - U.S. EPA/FWS data collected in 1985 (Appendix 6.2) and USACOE (1970, 1972, 1982) and MDNR (1978) unpublished data)



"RAP Sediment Criteria" for Manganese

- non polluted (< 300 mg/kg)
- moderately polluted (300 - 500 mg/kg)
- heavily polluted (> 500 mg/kg)

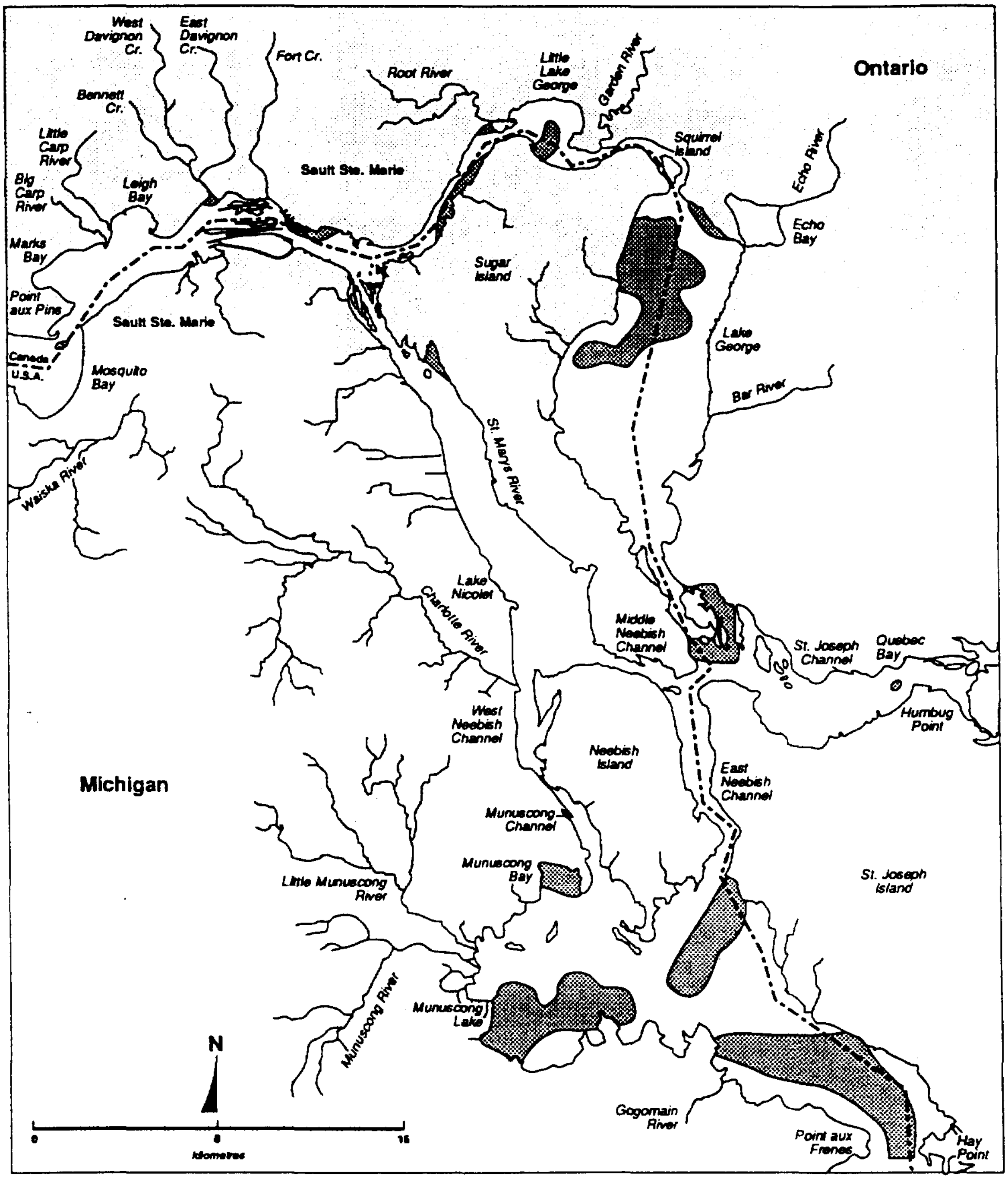
Figure 6.32

St. Marys River Remedial Action Plan

Spatial distribution of nickel contamination in surficial sediment in the St. Marys River, 1985

Sediment classification is based on "RAP Criteria Guidelines" (Table 6.6)

(prepared by MDNR from OMOE - U.S. EPA/FWS data collected in 1985 (Appendix 6.2) and USACOE (1970, 1972, 1982) and MDNR (1978) unpublished data)



"RAP Sediment Criteria" for Nickel

- non polluted (< 20 mg/kg)
- moderately polluted (20 - 50 mg/kg)
- heavily polluted (> 50 mg/kg)

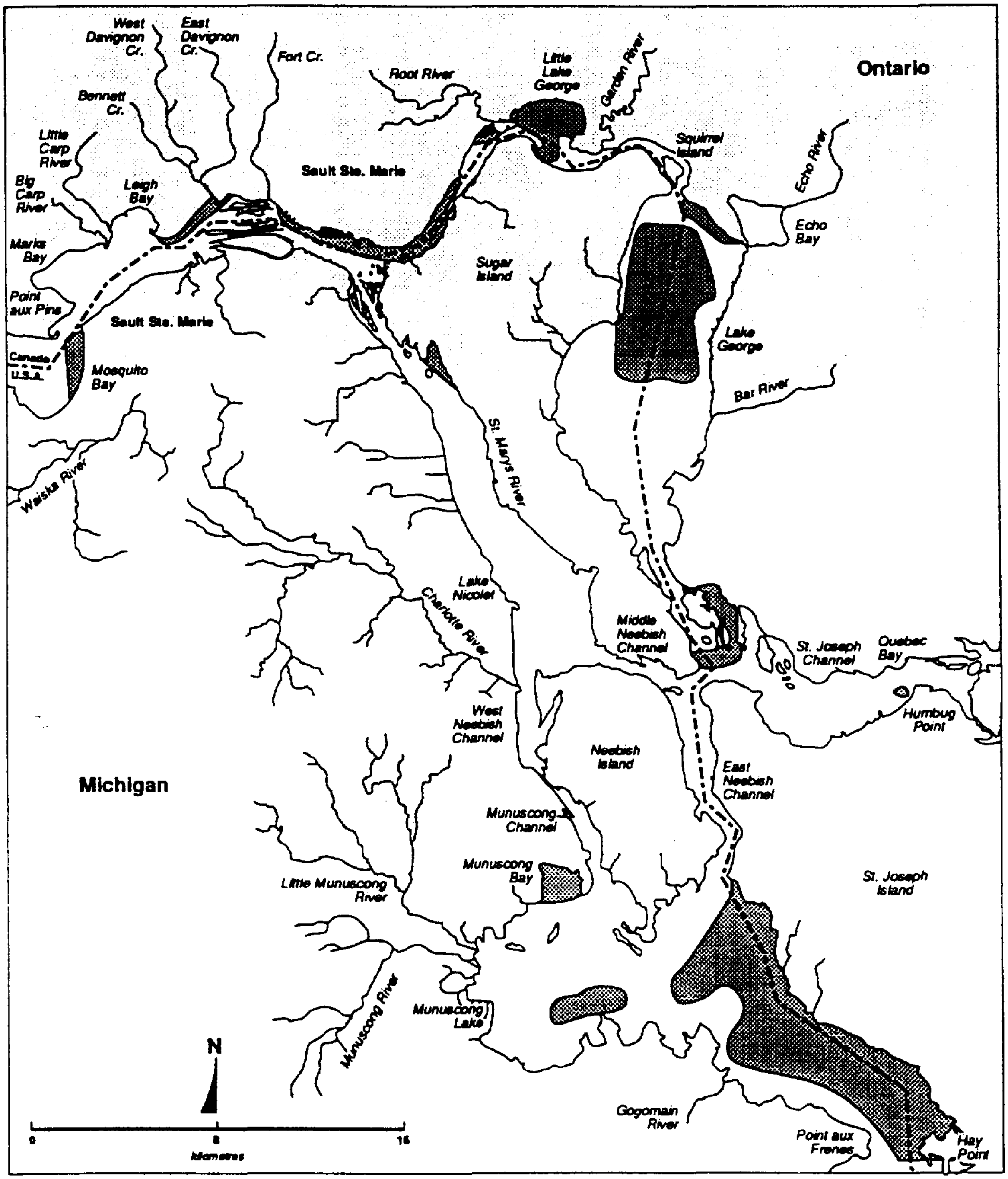
Figure 6.33

St. Marys River Remedial Action Plan

Spatial distribution of copper contamination in surficial sediment in the St. Marys River, 1985

Sediment classification is based on "RAP Criteria Guidelines" (Table 6.6)

(prepared by MDNR from OMOE - U.S. EPA/FWS data collected in 1985 (Appendix 6.2) and USACOE (1970, 1972, 1982) and MDNR (1978) unpublished data)



"RAP Sediment Criteria" for Copper

- non polluted (< 25 mg/kg)
- moderately polluted (25 - 50 mg/kg)
- heavily polluted (> 50 mg/kg)

Table 6.7 shows that 49% of the OMOE samples and 34% of the U.S.EPA/FWS samples exceeded the sediment pollution guideline for Cu. The U.S.EPA moderately polluted guideline for Ni (20-50 mg/kg) was exceeded in 34% of the U.S.EPA/FWS samples and in 21% of the OMOE samples.

6.2.3.6 Cadmium, Mercury and Cyanide

The MDNR 1978 survey (Kenaga 1979) and the 1985 surveys revealed small scattered areas of sediment moderately polluted ("RAP Sediment Criteria") with cadmium (Figure 6.34). These areas occur adjacent to the Cannelton Industries waste site (two sediment samples contained 1.9 and 2.0 mg/kg Cd), along the Michigan shore downstream of the Sault Edison Power Canal, Little Lake George and Lake George (Kenaga 1979, USACOE 1970, 1972, 1982 unpublished data and MDNR 1987 unpublished data). The remainder of the St. Marys River has been classified as non-polluted with respect to cadmium. Table 6.7 shows only 4% of the U.S.EPA/FWS samples and 3% of the OMOE samples exceeded the OMOE sediment pollution guideline for cadmium. 1985 concentrations throughout the river ranged from 0.20 to 1.8 mg/kg (Table 6.8).

Only two sediment samples from the 1985 survey had levels of mercury classed as moderately polluted (0.3 to 0.9 mg/kg) by the "RAP Sediment Criteria". One sample was located in the Rapids at the downstream end (0.38 mg/kg Hg) and the other was from the upper part of Lake Munuscong (0.31 mg/kg Hg). Both theses samples exceed the Ontario OWDG criterion of 0.3 mg/kg.

OMOE surveys of sediment quality in 1973 and 1983 showed that sediments in the vicinity of the Algoma Slip and downstream along the Ontario shore were heavily polluted with cyanide (Kauss 1986). However, cyanide levels as high as 14 mg/kg in 1973, were not detected in 1983. The maximum 1983 cyanide value was 0.015 mg/kg (Kauss 1986). The 1985 U.S.EPA/FWS survey data showed the majority of sediment samples to be moderate to heavily polluted (Appendix 6.2) however, the credibility of the analysis is in doubt. Because all samples that detected cyanide were either 0.1 mg/kg or greater. It is possible that the samples were too small or interferences affected the results (Hesselberg and Hamdy 1987).

6.2.3.7 Oil and Grease

The 1973 and 1983 OMOE surveys showed that surficial sediment was heavily contaminated with oil and grease along the Ontario shore from the Algoma Steel Slag site and Slip downstream to Sugar Island (Figure 6.35). Maximum oil and grease levels exhibited little change from 1973 (19,000 mg/kg) to 1983 (17,630 mg/kg); however, the areal extent of high oil and grease levels had slightly decreased by 1983 (Figure 6.35). The "RAP Sediment Criteria" indicates that surficial sediments along both shorelines of the Lake George Channel, all of Little Lake George, the centre of Lake George, the entrance to the St. Joseph Channel and lower Lake Nicolet were heavily contaminated (>2000 mg/kg) with oil and grease in 1985 (Figure 6.36). In addition moderately polluted sediments occur along the Michigan shoreline downstream of the Sault Edison Power Canal and in upper Lake Nicolet. The highest values were found at the entrance to the St. Joseph Channel (10,800 mg/kg) and in the West Neebish Channel (16,500 mg/kg) (Appendix 6.2). Table 6.9 shows that the areas downstream of Algoma Steel, Little Lake George and Lake George had the highest number of oil and grease exceedences.

6.2.3.8 Total PCBs

Little information is available on PCBs in sediments from the 1973 OMOE survey. 1983 data identified several areas with elevated levels of PCBs in sediments (up to 0.455 mg/kg) located at the entrance to the Great Lakes Power Canal, downstream of the locks along the Ontario shore, both upstream and downstream of the Sault Edison Power Canal on the Michigan shore and at the East End WPCP (Figure 6.37).

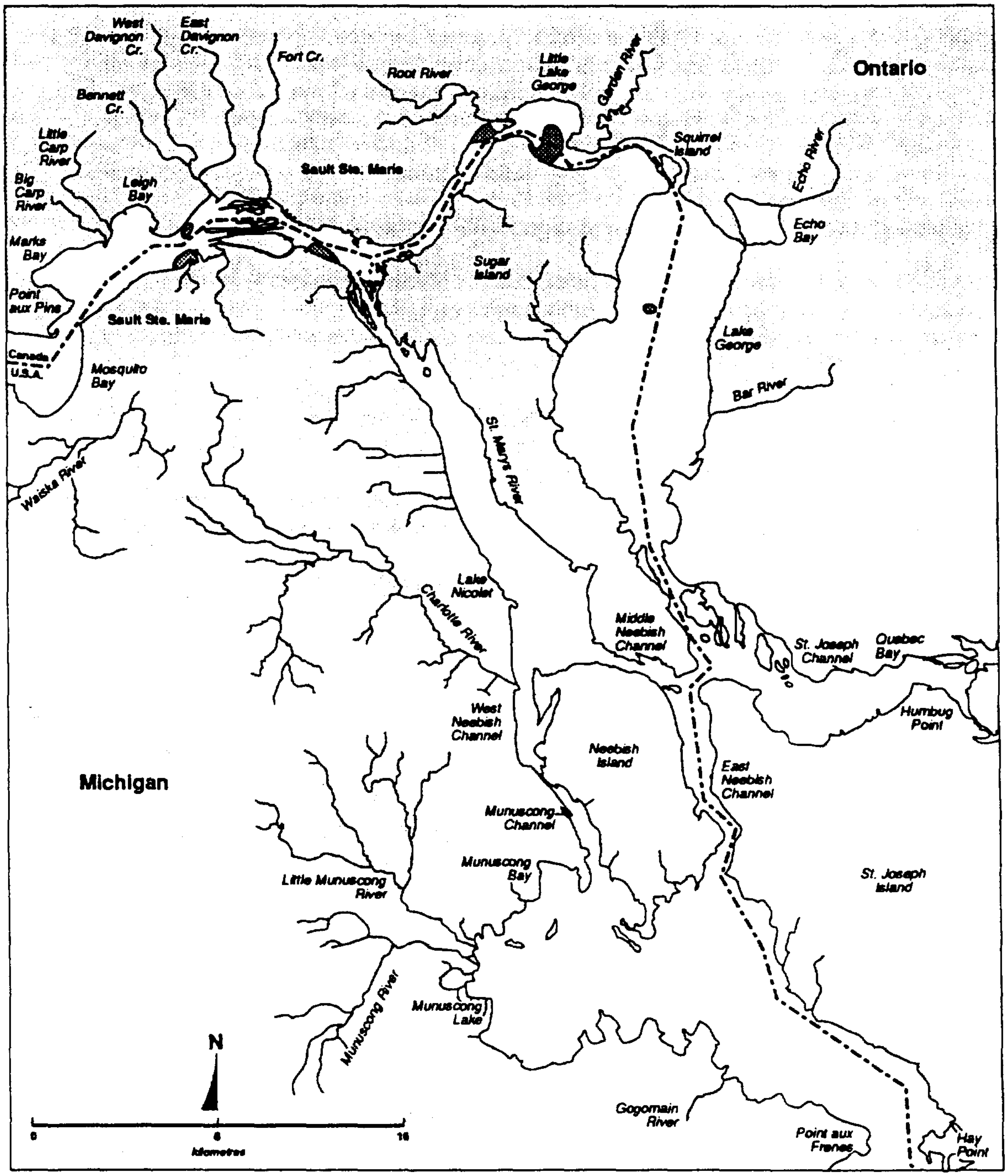
Figure 6.34

St. Marys River Remedial Action Plan

Spatial distribution of cadmium contamination in surficial sediment in the St. Marys River, 1985

Sediment classification is based on "RAP Criteria Guidelines" (Table 6.6)

(prepared by MDNR from OMOE - U.S. EPA/FWS data collected in 1985 (Appendix 6.2) and USACOE (1970, 1972, 1982) and MDNR (1978) unpublished data)



"RAP Sediment Criteria" for Cadmium

- non polluted (< 1 mg/kg)
- moderately polluted (1 - 6 mg/kg)
- heavily polluted (> 6 mg/kg)

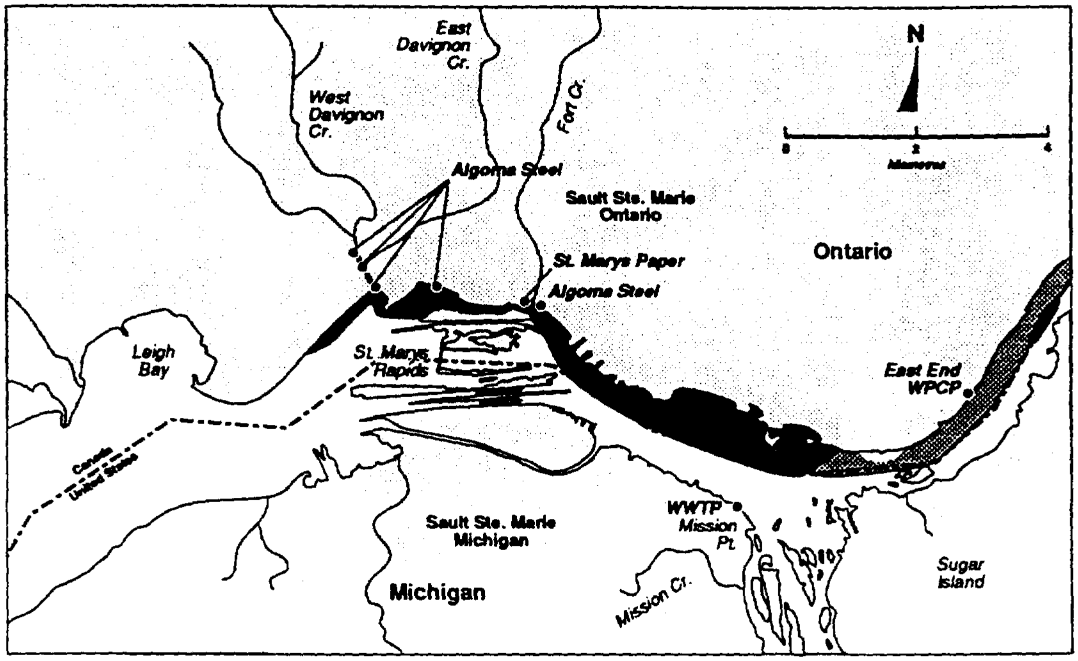
Figure 6.35

St. Marys River Remedial Action Plan

Spatial distribution of oil and grease in St. Marys River surficial sediments in 1973 and 1983

(from Kauss 1986)

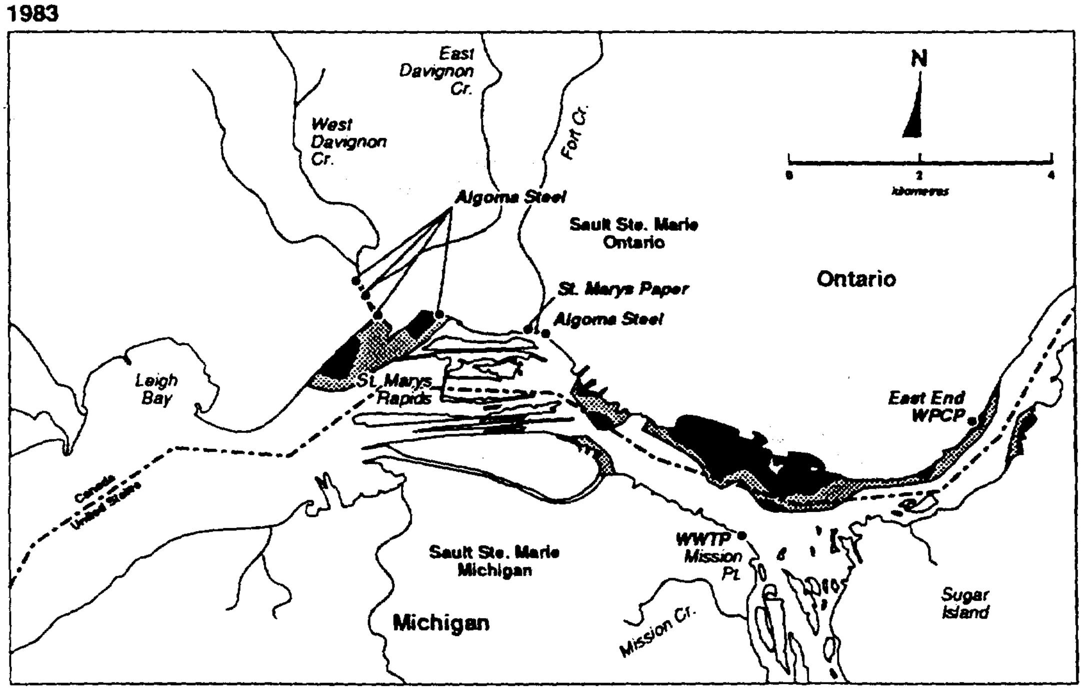
1973



Zone (mg/kg)	Range (mg/kg)
< 1,000	44 - 800
1,000 - 2,000	1,000 - 1,700 (moderate)
> 2,000	2,000 - 19,000 (heavy)

• point source discharge location

1983



Zone (mg/kg)	Range (mg/kg)
< 1,000	210 - 930
1,000 - 2,000	1,050 - 1,870 (moderate)
> 2,000	2,050 - 17,630 (heavy)

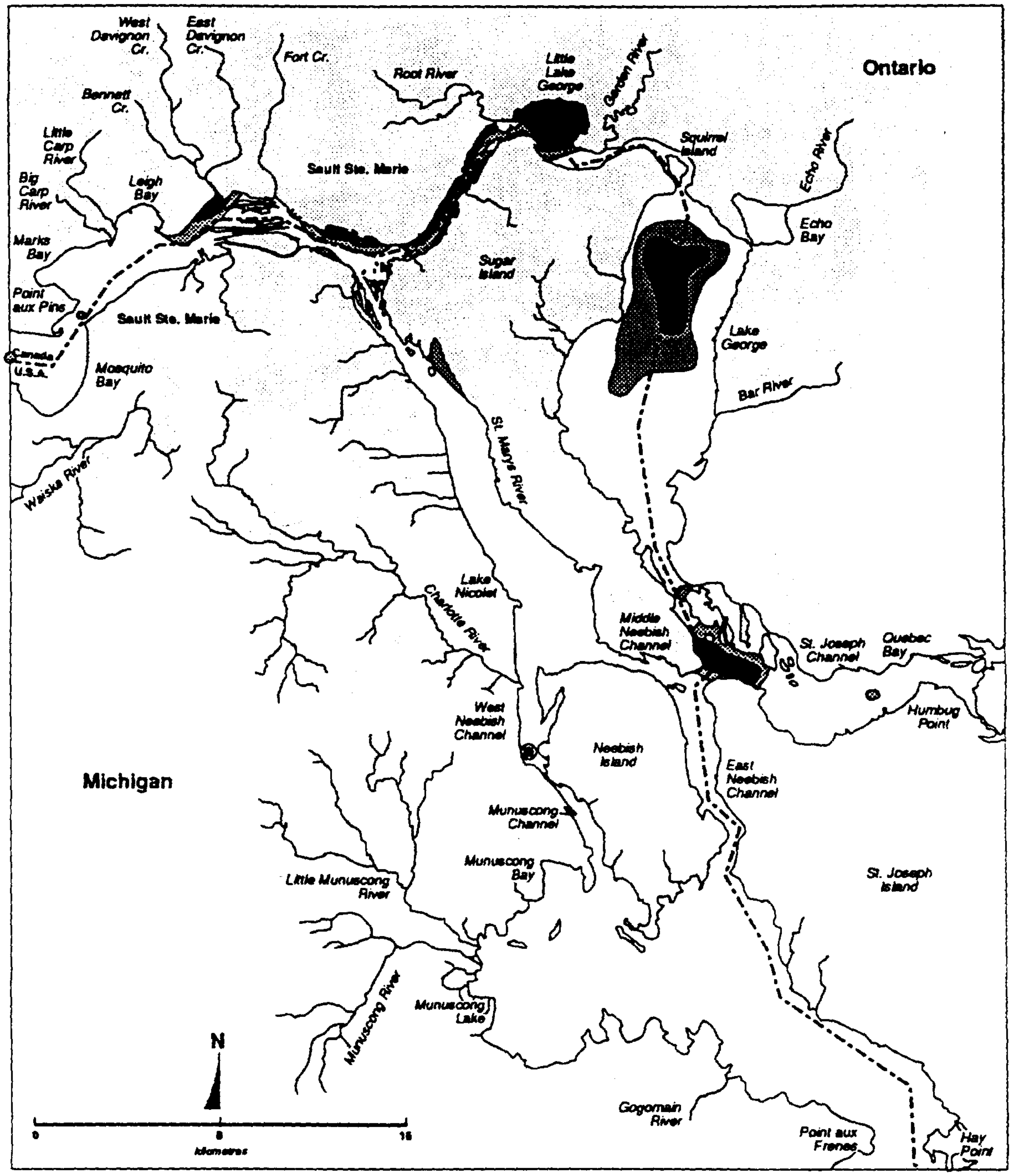
• point source discharge location

St. Marys River Remedial Action Plan

Spatial distribution of oil and grease contamination in surficial sediment in the St. Marys River, 1985

Sediment classification is based on "RAP Criteria Guidelines" (Table 6.6)

(prepared by MDNR from OMOE - U.S. EPA/FWS data collected in 1985 (Appendix 6.2) and USACOE (1970, 1972, 1982) and MDNR (1978) unpublished data)



"RAP Sediment Criteria" for Oil and Grease

- non polluted (< 1000 mg/kg)
- moderately polluted (1000 - 2000 mg/kg)
- heavily polluted (> 2000 mg/kg)

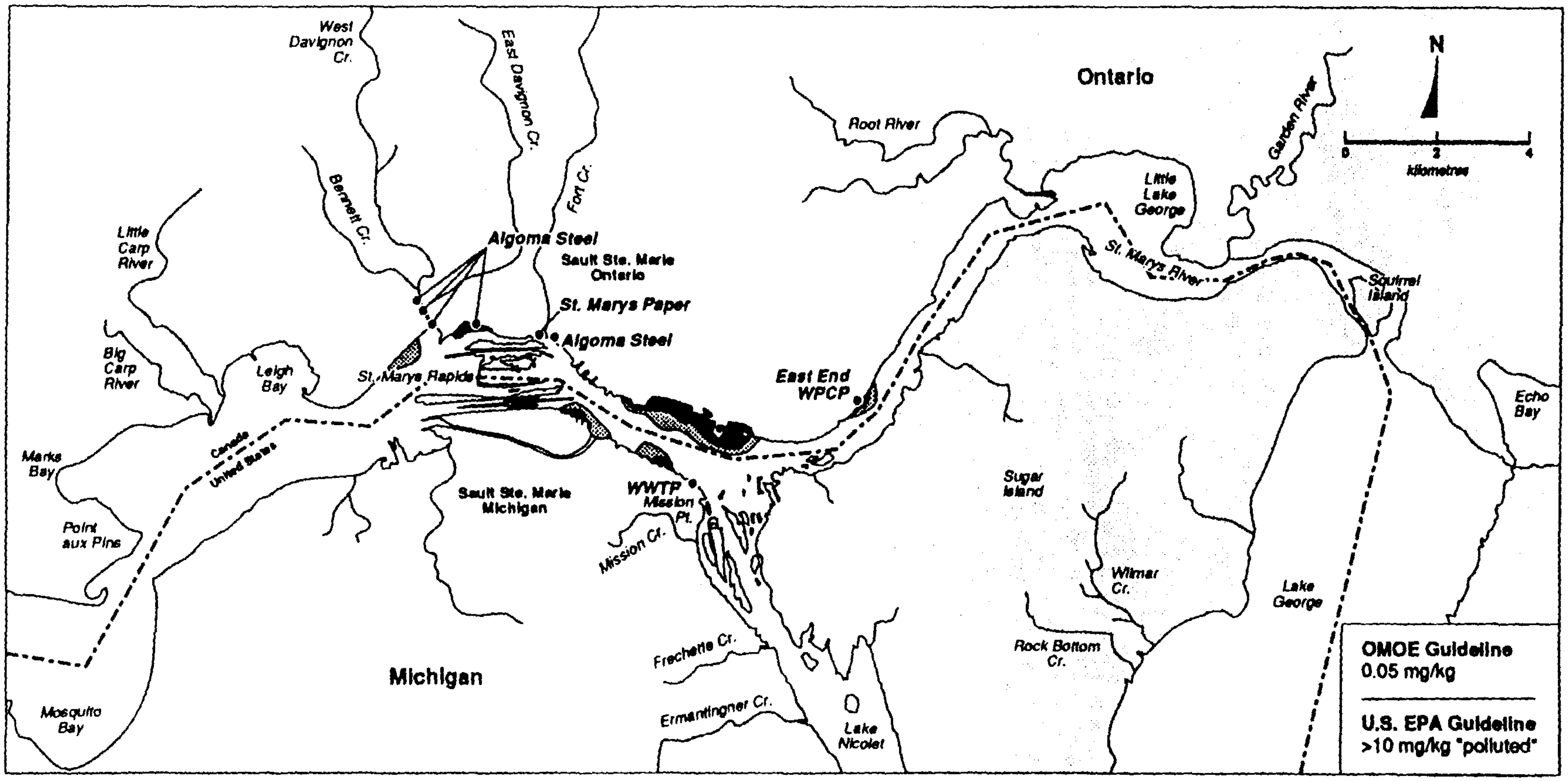
Figure 6.37

St. Marys River Remedial Action Plan

Spatial distribution of PCBs in St. Marys River surficial sediments in 1983

The zones and ranges were statistically determined

(from Kauss 1986)



Zone (mg/kg)	Range (mg/kg)
< 0.02	< 0.02
0.02 - 0.05	0.02 - 0.05
> 0.05	0.06 - 0.455

• point source discharge location

Twenty-seven percent of the U.S. EPA/FWS samples and 14% of the OMOE samples in 1985 exceeded the Ontario OWDG of 0.05 mg/kg for PCBs (Table 6.7). The maximum concentrations of total PCBs detected by the OMOE was 0.250 mg/kg. The maximum concentration of total PCBs detected by the U.S.EPA/FWS was 3.306 mg/kg from station #63 in the Middle Neebish Channel (Figure 6.24). The range of total PCB concentrations in the remaining 124 samples collected by the U.S.EPA/FWS was "not detected" to 0.145 mg/kg (Appendix 6.2). There are no known sources of PCBs near the Middle Neebish Channel.

The "RAP Sediment Criteria" identify a number of areas throughout the St. Marys River are moderately contaminated (0.05-9.99 mg/kg) with PCBs, particularly the East and West Neebish Channels, Munuscong Bay and Munuscong Lake (Figure 6.38).

The nature of the concentration contour interval used in Figure 6.37 for the 1983 data, indicates that there may have been some historical point sources of PCBs on both sides of the River.

6.2.3.9 Total PAHs

Fifteen surficial sediment samples were analyzed for PAH content during the 1985 OMOE survey (Figure 6.39). The highest total PAH value was found at station 115 in the Algoma Slip (711 mg/kg) (Kauss and Hamdy 1991). This station also had the highest concentrations of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(g,h,i)perylene, quinoline, carbazole, acridine, benzo(a)acridine, benzothiophene and dibenzothiophene (Appendix 6.4). Figure 6.39 also shows that both total and individual PAHs generally decreased downstream. High concentrations of total PAHs were found along the Michigan shore immediately downstream of the Sault Edison Electric Co. Canal (Figure 6.39). Maximum survey concentrations of chrysene, benzo(a)anthracene, benzo (b/k)fluoranthene, benzo(j)fluoranthene, benzo(e)pyrene, perylene, benzo(a)pyrene and dibenzo(a,h)anthracene were also found just downstream of the Sault Edison Power Canal (Appendix 6.4).

There are no available objectives or guidelines for total PAHs in sediments. The IJC (1983) has recommended that benzo(a)pyrene in sediment not exceed 1 mg/kg. Benzo(a)pyrene exceeded the IJC guideline in 60% of the samples (9 samples out of 15) taken from the St. Marys River.

The percent of mutagenic and carcinogenic PAHs in bottom sediment was calculated using values in Appendix 6.4 and the information in Table 6.4. Samples with the highest total PAH concentration do not necessarily contain the highest percentage of carcinogenic PAH compounds. For example, the sample collected adjacent to the Slag Site contained 77 mg/kg total PAHs of which 78% are carcinogenic. Two samples collected in and at the mouth of the Algoma Slip contained 711 and 71 mg/kg total PAHs respectively with 19% and 25% being carcinogenic. Of interest, a sediment sample collected immediately downstream of the Sault Edison Power Canal contained 338 mg/kg total PAHs of which 48% are carcinogenic.

6.2.3.10 Loss On Ignition (LOI)

Percent loss on ignition (LOI) values are a rough approximation of the amount of organic matter in the sediments. The highest LOI values from the 1985 surveys occurred along the Ontario shore downstream of Algoma Steel and St. Marys Paper. Values ranged from 0.2 to 17.4% exceeding the Ontario OWDG (6%) and U.S. EPA criteria (5-8%). Table 6.9 indicates that the more stringent U.S. EPA criteria for LOI was exceeded in Little Lake George, Lake George and Lake Nicolet.

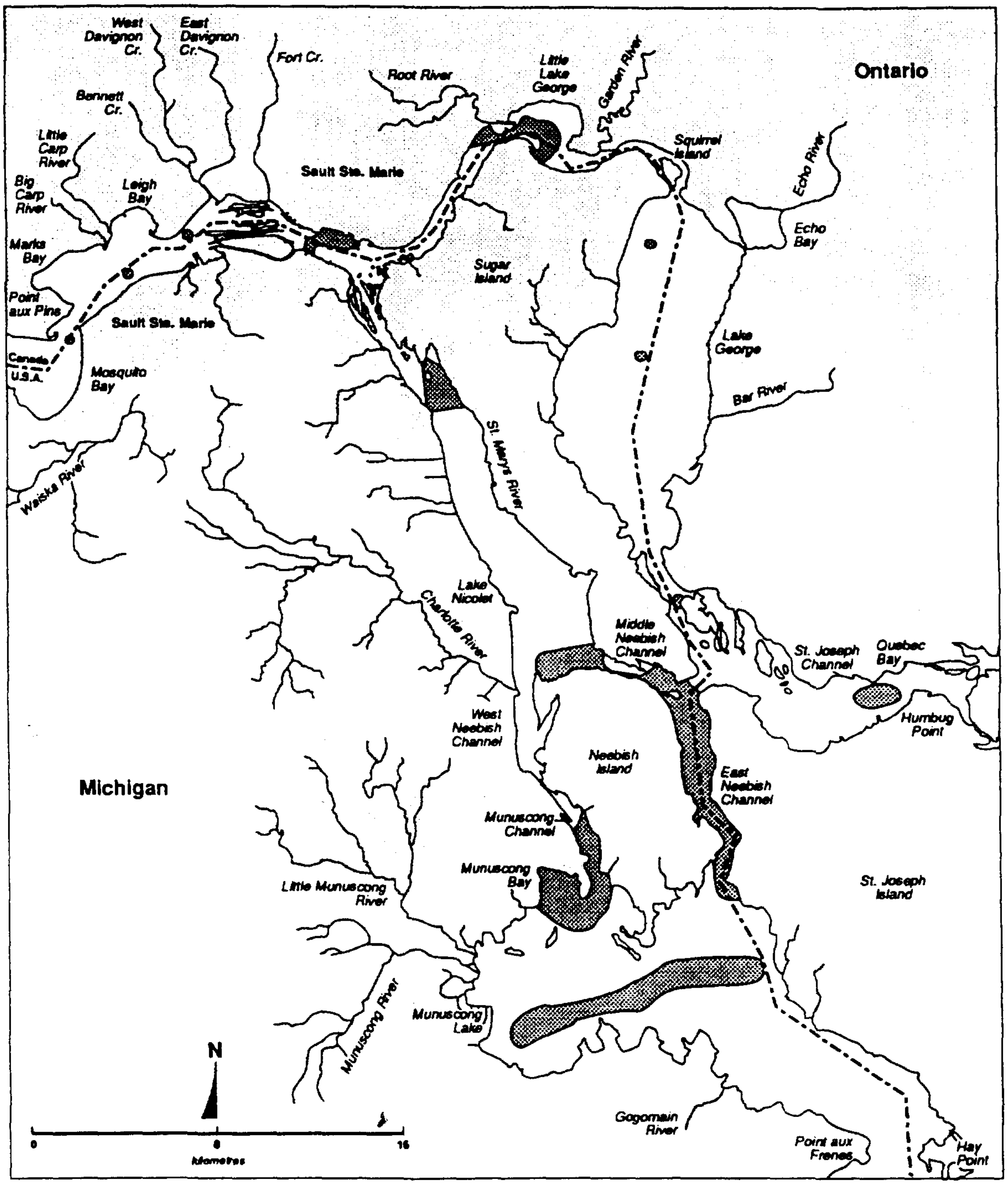
Figure 6.38

St. Marys River Remedial Action Plan

Spatial distribution of PCBs contamination in surficial sediment in the St. Marys River, 1985

Sediment classification is based on "RAP Criteria Guidelines" (Table 6.6)

(prepared by MDNR from OMOE - U.S. EPA/FWS data collected in 1985 (Appendix 6.2) and USACOE (1970, 1972, 1982) and MDNR (1978) unpublished data)



PCBs "RAP Sediment Criteria"	Range
non polluted (< 0.05 mg/kg)	ND to 0.049 mg/kg
moderately polluted (0.05 - 10.0 mg/kg)	0.05 - 3.306 mg/kg
heavily polluted (> 10.0 mg/kg)	-

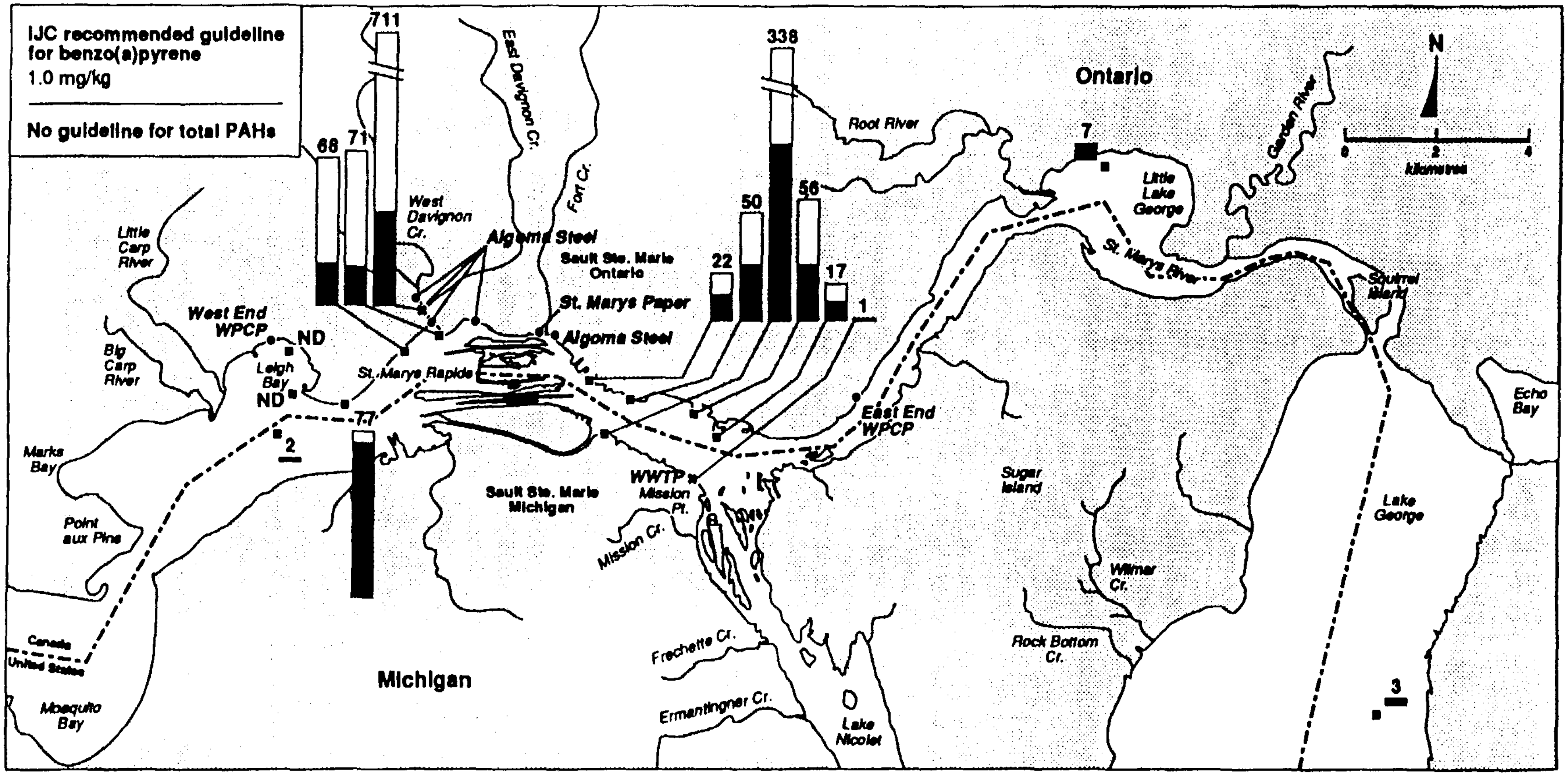
Figure 6.39

St. Marys River Remedial Action Plan

Total polycyclic aromatic hydrocarbons (PAHs) (mg/kg) in surficial sediments of the St. Marys River in 1985

Bar height is proportional to concentration; shaded portion of bars indicated the proportion of the total comprised of mutagenic and/or carcinogenic compounds

(from Kauss and Hamdy 1991 and UGLCCS 1988)



- ✱ sampling and point souurce discharge location
- • point source discharge location
- ▪ sampling location

ND Not Detected

6.2.3.11 Total Phosphorus Total (TP) and Kjeldahl Nitrogen (TKN)

The 1985 surveys showed that TP concentrations in sediment were highest along the Ontario shore downstream of Algoma Steel (180-760 mg/kg), in Little Lake George (380-750 mg/kg) and in Lake George (300-870 mg/kg). Although the maximum TP concentrations are similar in each of the three areas, the percent of samples exceeding the U.S. EPA moderately polluted criteria (420-650 mg/kg) suggests that the East End WPCP is a point source for phosphorus. Table 6.9 shows that 33% of the OMOE samples downstream of Algoma Steel at Sault Ste. Marie were in exceedence. However, further downstream at Little Lake George, 80% are in exceedence suggesting a source of phosphorus is present downstream of the town of Sault Ste. Marie. The percent exceedences decreases downstream from Little Lake George to Lake George (73%) indicating there are no major inputs of phosphorus to the river.

A similar trend for TKN is identified in Table 6.9. TKN exceedences did not occur in the 1985 samples downstream of Algoma Steel however, all samples from Little Lake George (1,500 to 3,000 mg/kg), which is downstream of the East End WPCP, exceeded the U.S. EPA criteria (1,000-2,000 mg/kg). TKN concentrations in Lake George ranged from not detected to 2,100 mg/kg with only 50% in exceedence.

6.2.4 Summary

Sediments along the Ontario shore from the Algoma Steel Slag Site above the Rapids as well as downstream of the Great Lakes Power Canal to Sugar Island, the northwest shore of Sugar Island within the Lake George Channel, Little Lake George and the north central part of Lake George are "heavily" polluted ("RAP Sediment Criteria) with iron, zinc, lead, manganese, cadmium, nickel, copper, chromium, arsenic and oil and grease. Sediments at the entrance to St. Joseph Channel and the West Neebish Channel are heavily polluted with oil and grease. The Michigan shore adjacent to the Cannelton waste disposal site and the Ontario shore downstream of the locks is heavily polluted with chromium. High concentrations of total PAHs occur downstream along the Ontario shore from the Algoma Steel property to the entrance of Lake George Channel, on the Michigan shore downstream of the Sault Edison Electric Co. Canal.

Sediments "moderately" polluted ("RAP Sediment Criteria") with chromium, nickel, copper and PCBs occur throughout the St. Marys River AoC particularly in Little Lake George, Lake George, Munuscong Lake, East and West Neebish and St. Joseph Channels. However, natural background levels of chromium and copper may be high enough to be classified as moderately polluted.

Contaminants, which exceed the Ontario OWDG and the U.S. EPA "moderately polluted" guidelines for dredged materials are summarized in Table 6.10. Parameters exceeding the most stringent of these guidelines downstream of the Algoma Slip and along the Ontario shore, in Little Lake George and Lake George include iron, chromium, zinc, lead, arsenic, manganese, nickel, copper, oil and grease, PCBs, LOI, total phosphorus and TKN. In addition, total PAHs exceeded the proposed Ontario Sediment Quality Guideline of 2.0 mg/kg at these locations.

Lake Nicolet exceedences included iron, chromium, zinc, lead, arsenic, manganese, nickel, copper, cadmium, oil and grease, PCBs, LOI, total phosphorus, and TKN. Chromium, nickel, copper, mercury (one sample), and PCBs were exceeded in Munuscong Lake. Chromium and cadmium exceedences occur at the head of the St. Marys River along the Michigan shore at the Cannelton Industries waste disposal site.

Historical information from a Lake George core sample shows that levels of total PAHs, total PCBs, total DDT, zinc, chromium lead and oil and grease peaked in the 1960's or 1970's and have since declined. Loadings of PCBs and DDT have declined due to decreased use while decreases in the inputs of other contaminants are probably due to improved waste treatment and decreased production at Algoma Steel. The extent of heavily polluted sediment along the Ontario shore downstream of the Algoma site has also

Table 6.10 Summary of parameters in bottom sediment exceeding the OMOE Open Water Disposal Guidelines for dredged material (OWDG) and U.S. EPA "moderately polluted" guideline for Disposal of Great Lakes Harbor Sediments for the St. Marys River Area of Concern.

Parameter	Guideline	(mg/kg)	Year and Location of Exceedence (mg/kg)
Iron	Ontario OWDG[1] U.S. EPA[2]	10,000 17,000-25,000	1985-Algoma Slip and Ontario shore downstream of Algoma Steel (11,000-150,000; range) -Little Lake George (19,000-39,000; range) -Lake George (8,600-42,00; range) -Lake Nicolet embayment (5,500-21,000; range)
Chromium	Ontario OWDG U.S. EPA	25 25-75	1978-Michigan shore downstream of Cannelton Industries waste site (20-2200; range) -Adjacent to Cannelton Industries waste site (4,000; max) 1985-Ontario shore downstream of Algoma Steel (10-79; range) -Little Lake George (7-61; range) -Lake George (0-56; range) -Lake Nicolet (5-49; range) -Lake Munuscong (16-70; range) -Lime Island Channel (4-68; range) 1991-Michigan shore downstream of Cannelton Industries waste site at "Tannery Bay" (31,000; max)
Zinc	Ontario OWDG U.S. EPA	100 90-200	1973-Algoma Slip and along Ontario shore downstream of Algoma Steel to head of Lake George Channel (9.4-1100; range) 1983-Algoma Slip; downstream of Slag Site, Ontario shore downstream of Algoma Steel to head of Lake George Channel and at East End WPCP (7.1-654; range) 1985-Downstream of Slag Site, Ontario shore downstream of Algoma Steel (32-660; range) -Little Lake George (29-470; range) -Lake George (16-260; range) -Lake Nicolet embayment (11-140; range) -Lime Island Channel (6-110; range)
Lead	Ontario OWDG U.S. EPA	50 40-60	1985-Downstream of Slag Site, Ontario shore downstream of Algoma Steel and Michigan shore downstream of Sault Edison Power Canal (8.2-250; range) -Little Lake George (7-130; range) -Lake George (3.8-76; range) -Lake Nicolet embayment (2.8-43; range)
Arsenic	Ontario OWDG U.S. EPA	8 3-8	1985-Along the Ontario shore from the Slag Site to the head of the Lake George Channel (2.97-43.9; range) -Little Lake George (4.14-10.21; range) -Lake George (1.96-14.82; range) -Lake Nicolet embayment (1.35-4.93; range)
Manganese	U.S. EPA	300-500	1985-Along the Ontario shore from the Slag Site to the head of the Lake George Channel (140-3,700; range) -Little Lake George (220-480; range) -Lake George (100-640; range) -Lake Nicolet embayment (70-7,000; range)

Table 6.10 (Cont'd)

Parameter	Guideline (mg/kg)		Year and Location of Exceedence (mg/kg)
Nickel	Ontario OWDG U.S. EPA	25 20-50	1985-Ontario shore downstream of Algoma Steel (6-35; range) -Little Lake George (4-30; range) -Lake George (2-31; range) -Lake Nicolet embayment (2.0-25; range) -Lake Munuscong (4-44; range) -Lime Island Channel (3-38; range)
Copper	Ontario OWDG U.S. EPA	25 25-50	1985-Ontario shore downstream of Slag Site to head of Lake George Channel (4.8-52; range) -Little Lake George (7-110; range) -Lake George (4-59; range) -Lake Nicolet embayment (4-41; range) -Lake Munuscong (8-41; range) -Lime Island Channel (2-42; range)
Cadmium	Ontario OWDG U.S. EPA	1.0 6.0*	1978-Michigan shore adjacent to Cannelton Industries waste site (1.9 and 2.0; two samples) 1985-Michigan shore just downstream of Sault Edison Power Canal (0.2-1.1; range) -Little Lake George (0.2-1.8; range) -Lake George (0.2-1.1; range) -Lake Nicolet embayment (0.2-1.2; range)
Mercury	Ontario OWDG U.S. EPA	0.3 1.0*	1985-Two samples, one at downstream end of Rapids (0.38), one in Lake Munuscong (0.31)
Cyanide	Ontario OWDG U.S. EPA	0.1 0.1-0.25	1973-Algoma Slip and downstream along Ontario shore (14; max)
Oil and Grease	Ontario OWDG U.S. EPA	1,500 1,000-2,000	1973-Algoma Slip; Algoma Slag Site downstream along Ontario shore to Sugar Island (44-19,000; range) 1983-Algoma Slip; Algoma Slag Site downstream along Ontario shore to Sugar Island (210-17,360; range) 1985-Algoma Slip; Algoma Slag Site downstream along Ontario shore to Little Lake George (0-5420; range) -Little Lake George (360-9,320; range) -Lake George (0-5,090; range) -Lake Nicolet embayment (0-1,195; range) -Lime Island Channel (0-1,250; range) -Entrance to St. Joseph Channel (10,800; max) -West Neebish Channel (16,500; max)

Table 6.10 (Cont'd)

Parameter	Guideline (mg/kg)		Year and Location of Exceedence (mg/kg)
PCBs	Ontario OWDG U.S. EPA	0.05 10.0*	1983-Entrance to Great Lakes Power Canal, Ontario shore downstream of locks, Michigan shore both upstream and downstream of Sault Edison Power Canal and at the East End WPCP (0.02-0.455; range) 1985-Ontario shore downstream of Algoma Steel (ND-0.099; range) -Little Lake George (ND-0.362; range) -Lake George (ND-0.065; range) -Lake Nicolet (ND-0.101; range) -Lake Munuscong (0.029-0.145; range) -Lime Island Channel (0.024-0.052; range) -Middle Neebish Channel (3.306; one sample)
PAH	Ontario SQG[3]	2.0	1985-Algoma Slip (711; max) -Ontario shore downstream of Algoma Steel (17-56; range) -Downstream of Sault Edison Power Canal (338; one sample) -Little Lake George (7; one sample) -Lake George (3; one sample)
LOI	Ontario OWDG U.S. EPA	6 % 5 % - 8%	1985-Along the Ontario shore downstream of Algoma Steel (0.2%-17.4%; range) -Little Lake George (4.4%-9.7%; range) -Lake George (0.25%-6.4%; range) -Lake Nicolet (0.73%-7.1%; range)
Total Phosphorus	Ontario OWDG U.S. EPA	1,000 420-650	1985-Along the Ontario shore downstream of Algoma Steel (180-760; range) -Little Lake George (380-750; range) -Lake George (300-870; range) -Lake Nicolet (150-500; range)
TKN	Ontario OWDG U.S. EPA	2,000 1,000-2,000	1985-Little Lake George (1,500-3,000; range) -Lake George (ND-2,100; range) -Lake Nicolet (300-2,900; range)

1 Ontario Ministry of the Environment Open Water Disposal Guidelines for Dredged Materials.
2 U.S. EPA Interim Guidelines for the Disposal of Great Lakes Harbor Sediments - values shown are ranges encompassing the "Moderately Polluted" classification, values above the maximum noted are in the "Heavily Polluted" class.
3 Ontario Proposed Sediment Quality Guidelines, Lowest Effect Level (Appendix 6.3)

* heavily polluted category only, moderately polluted values are either not determined (Hg and Cd) or to be calculated on a case-by-case basis (PCBs).

decreased. For example, the areal extent of zinc and oil and grease sediment contamination decreased from 1973 to 1983. This decrease was probably due to a decrease in contaminant loadings and an increase in flow through the Great Lakes Power Canal in 1982.

6.3 PHYTOPLANKTON

6.3.1 Background

To date, most studies on phytoplankton and periphyton of Lake Superior and the St. Marys River have been qualitative to semi-quantitative, and are generally restricted to diatoms and other macro-phytoplankton. Nonetheless, scientists have often used the lake and river as examples of low productivity (oligotrophic) conditions to confirm changes that have occurred in other Laurentian Great Lakes owing to cultural enrichment. For example, Holland (1965) examined samples collected between June and November, 1964 and indicated that diatoms (Bacillariophyceae), including four species of *Cyclotella* (*C. glomerata*, *C. stelligeria*, *C. ocellata*, and *C. k tzingiana*) dominated the flora of Lake Superior. The oligotrophic nature of the lake was indicated by the presence of species of the genus *Cyclotella*. Foged (1954) and Schelske *et al.* (1972) also noted the dominating role of the diatoms, and especially species of the genus *Cyclotella*, at both nearshore and mid-lake stations.

6.3.2 Community Composition

Liston *et al.* (1981, 1983 and 1986) have concluded that diatoms dominate the macro-phytoplankton of the river, and that the species present are indicative of oligotrophic waters similar to those reported for Lake Superior by Holland (1965), Schelske *et al.* (1972), Feldt *et al.* (1973), Vollenweider *et al.* (1974) and Munawar and Munawar (1978).

The 14 most common diatoms reported by Liston *et al.* (1986) from a listing of 72 are shown in Table 6.11. Most are planktonic, with *Achnanthes minutissima* being the only benthic algae listed in Table 6.11. Many other species, identified but not included in Table 6.11, have a benthic affinity. As explained by Duffy *et al.* (1987), the benthic forms are apparently dislodged from the river bed and incorporated into the planktonic component by currents. "Such a mix of typically planktonic species with those that are benthic in habitat was also observed by Kreis *et al.* (1983) in the plume of the St. Marys River in Lake Huron. Benthic populations comprised as much as 40% of the total algal assemblage in terms of cell volume, while the remainder were truly planktonic in occurrence." (Duffy *et al.*, 1987).

Table 6.11 The most common diatoms found in the Lake Nicolet reach of the St. Marys River during 1982 (Listen *et al.*, 1986).

Achnanthes minutissima
Asterionella formosa
Cyclotella comta
Cyclotella glomerata
Cyclotella k tzingiana
Fragilaria construens
Fragilaria crotonensis
Melosira islandica
Rhizosolenia eriensis
Stephanodiscus hantzschii
Synedra acus
Synedra rana
Synedra ulna
Tabellaria fenestrata

The OMOE's 1965 to 1982 monitoring program at Gros Cap and the old Sault Ste. Marie, Ontario power dam intake identified 178 taxa, with green algae (Chlorophyte) and diatoms (Bacillariophyceae) dominating at 34% and 25% respectively, followed by the chrysophytes (Chrysophyceae) at 21% and blue greens (Cyanophyceae) at 11% (Hopkins 1986). The remaining 9% was comprised of dinoflagellates (Dinophyceae), cryptophytes (Cryptophyceae) and euglenoids (Euglenophyceae). These results are very similar to those of Munawar and Munawar (1978) for the open waters of Lake Superior in 1973: 31% for diatoms, 22% for greens, 20% for chrysophytes and 12% for blue-greens.

The diatoms *Fragilaria crotonensis*, *Tabellaria fenestrata*, *Asterionella formosa*, *Ceratoneis* spp., *Rhizosolenia eriensis*, *Cyclotella* sp., *Stephanodiscus* sp., and *Synedra* sp. were most noticeable during the spring and summer periods (Hopkins 1986).

The following comments relate to the ecological requirements of a number of the above-noted species.

Veal and Michalski (1971) and Stoermer (1968) concluded that *Tabellaria fenestrata*, has a preference for a nutrient-poor regime and was an important component of the spring flora in Midland Bay, Hog Bay and Sturgeon Bay, but was virtually absent from Penetang Bay, the most nutrient rich of the four bays. The relative abundance of Tabellaria fenestrata outside the thermal bar of Lake Michigan was believed to be related to lower nutrient conditions characteristic of off-shore waters (Stoermer 1968). Considering that this species was either the most abundant or second most abundant diatom at all times of the year in the St. Marys River from 1959-1961, together with the OMOE's findings and the above comments on ecological requirements, one can infer that nutritional characteristics have been relatively consistent in eastern Lake Superior and in the St. Marys River over the past 30 years.

Numerous investigators including Rodhe *et al.* (1958), Nalewajko (1962), Hutchinson (1957), Vollenweider and Saraceni (1964), Stockner and Bensen (1967) and Michalski *et al.*, (1973) associate *Fragilaria crotonensis* with eutrophic conditions. However, Stoermer and Yang (1970) indicate this species may tolerate a wide range of trophic levels. As noted above, *Fragilaria crotonensis* was an important component of the flora in eastern Lake Superior and the St. Marys River. *Rhizosolania eriensis*, a small, transparent diatom, is frequently associated with oligotrophic waters. For example, Putnam and Olsen (1961) considered it to be an important component of the flora of Lake Superior, and Hohn (1969) described its long-term decline in the Bass Islands area of Lake Erie, presumably as a result of eutrophication. Significantly, *Rhizosolenia eriensis* was frequently encountered in the OMOE's two monitoring programs.

A good deal of conjecture prevails with respect to the ecological niche for *Asterionella formosa*; it has been associated with eutrophic and mesotrophic conditions (Pennington 1943 and Patrick and Reimer 1966). On the other hand, Rawson (1956) reported that *Asterionella formosa* is a characteristically oligotrophic organism in large North American lakes. Stoermer and Yang (1970) suggest that *Asterionella formosa* occupies a broad ecological niche, and that it may include a large number of sub-species and physiological strains which are not morphologically distinguishable. The OMOE's long-term monitoring programs indicate that this species is common to the waters of eastern Lake Superior and the St. Marys River, especially during the spring season.

The conspicuous absence of the diatoms *Fragilaria capucina* and *Melosira granulata* (species associated with eutrophic waters) from eastern Lake Superior and the St. Marys River, confirms the oligotrophic character of open waters in the AoC. However, certain localized areas can occasionally have elevated nutrient concentrations. In combination with slower currents and a longer residence time, these waters may contain different phytoplankton species than open waters of the river.

The most important blue-green species in the St. Marys River, mainly of the genera *Aphanothece* and *Chroococcus*) are typically found in the flora of unenriched lakes of Precambrian origin (Michalski 1971, Schindler and Nighswander 1970, Schindler and Holmgren 1971, and Michalski *et al.*, 1973). Significantly, the blue-green algae *Aphanizomenon flos-aquae* and *Anabaena flos-aquae*, which are common to highly enriched waters, were rarely encountered in the St. Marys River and Gros Cap phytoplankton assemblages, again emphasizing the oligotrophic nature of Lake Superior.

Scenedesmus sp. was the most numerous and consistently-occurring green algae, with low numbers *Oocystis* sp. appearing during the summer. Hutchinson (1957) included the latter species in his "oligotrophic chlorococcal plankton" classification.

Dinobryon sp., the most abundant dinoflagellate, reaches peak numbers during the late summer and early fall.

6.3.3 Standing Stocks

A seasonal, bimodal pattern of plankton development in larger lakes has been well-documented by Chandler (1940, 1942 and 1944), Davis (1954 and 1962) and Pennak (1946). Lake Ontario and portions of Lake Erie where the vernal and autumnal pulses occurred during April and/or May and in late August or early September respectively, peaks for Gros Cap usually developed later in July and August for the spring pulse, and in late October and November for the fall maximum. This delayed development is probably temperature-dependent and relates to the slow warming and cooling nature of Lake Superior. The bimodal pattern was not as clearly defined at the St. Marys River site as at Gros Cap, owing to short-term peaks which tend to obscure a definite pattern. Davis (1964), Michalski (1968) and Michalski *et al.* (1973) suggested that an increase in the intensity and duration of the spring and fall phytoplankton maxima reflected conditions of accelerated eutrophication. Such an increase was not observed at Gros Cap, again suggestive of the oligotrophic nature of Lake Superior. The St. Marys River short-term peaks are likely related to local environmental factors for example, influences of local currents and warming associated with a river system.

Since 1965, the OMOE has been analyzing phytoplankton samples collected from Sault Ste. Marie, Ontario municipal water intake. At the beginning of the monitoring program, the intake was located in the wall of the power canal in the St. Marys River. The main purpose of the monitoring program, implemented at many municipalities throughout the Great Lakes Basin, is to determine the effectiveness of various nutrient abatement measures on the near-shore enrichment. In 1985, the city moved its intake location to Gros Cap. Of the three intakes in the power canal, only one continues to be used by the city for its fish hatchery operation.

Between 1965 and 1982, the mean standing stock (cell volume) of phytoplankton at the Sault Ste. Marie water intake location was 103 Areal Standard Units per Ml (A.S.U./mL) or 0.332 mm^3/L (Table 6.12), and no significant year-to-year change was evident over the 18 years (Hopkins 1986). Samples collected immediately off Gros Cap between 1965 and 1973 for the purpose of locating a new intake pipe were characterized by similar results, with a nine year mean of 116 A.S.U./mL (Michalski 1975). Long-term standing stock data from a number of municipal water supply intakes in Table 6.13, confirms the oligotrophic nature of Lake Superior and the St. Marys River (Hopkins 1986).

6.3.4 Effects of Contaminants

Bioassays conducted with indigenous phytoplankton in Munuscong Lake revealed a significant enhancement of ultra-, micro-, and macro-phytoplankton productivity during sediment resuspension resulting from the passage of a large vessel (Munawar and Munawar 1978). This suggests the absence of pronounced sediment-bound toxicity in the lower river, but not necessarily in the upper river where sediments are more contaminated (see Section 6.2). Excessive amounts of algae have been observed in embayments and other slow-moving areas of the river. During the summer of 1990, OMOE received a number of citizens complaints regarding floating algae on the river downstream of the East End WPCP.

Table 6.12 Summary of phytoplankton data collected from the Sault Ste. Marie, Ontario water intake in the St. Marys River and from a sampling site offshore of Gros Cap, Lake Superior. All values are expressed as Areal Standard Units (A.S.U.) per mL. (One A.S.U. is equal to an area subtended by 0.003 mm^3/L) (Hopkins 1986, Michalski 1975).

Year	Sault Ste. Marie*			Gros Cap†		
	Maximum	Mean	Number of Samples	Maximum	Mean	Number of Samples
1965	308	108	11	295	149	12
1966	283	104	13	196	93	8
1967	1,360	237	23	374	166	23
1968	276	102	21	524	181	15
1969	1,017	135	26	212	74	24
1970	201	94	24	253	113	22
1971	159	56	21	367	113	24
1972	134	58	19	254	63	20
1973	133	63	18	245	95	14
1974	219	110	13			
1975	124	66	10			
1976	291	89	17			
1977	202	91	16			
1978	331	104	13			
1979	120	78	8			
1980	242	104	13			
1981	234	89	15			
1982	431	136	22			
Overall mean		103			116	

*Hopkins (1986)
†Michalski (1975)

6.3.5 Summary

Long-term monitoring of phytoplankton stocks in near shore waters of Lake Superior and in the upper reaches of the St. Marys River revealed low algal densities characteristic of oligotrophic waters. As well, the composition of the species assemblages was oligotrophic in character. However, certain localized areas can have nutrient concentrations resulting in different phytoplankton species than would be found in open waters of the river (see Section 6.1.2.7). The low productivity of the AoC was emphasized by comparing data on its phytoplankton composition with corresponding information from other sites on the Great Lakes. Of note is that species characteristic of nutrient-rich waters were conspicuously absent from the upper St. Marys River. Little is presently known about the effects of contaminants on phytoplankton numbers or productivity.

6.4 AQUATIC MACROPHYTES

The term 'aquatic macropytes' refers to macroscopic forms of aquatic vegetation and includes macroalgae (e.g. *Chara*, *Cladophora*), aquatic mosses and ferns, and aquatic angiosperms (flowering plants bearing seeds in a closed capsule).

Table 6.13 Summary of phytoplankton data from various Ontario Great Lakes water supply intakes (Hopkins 1986). All results are in Areal Standard Units (A.S.U.)/mL.

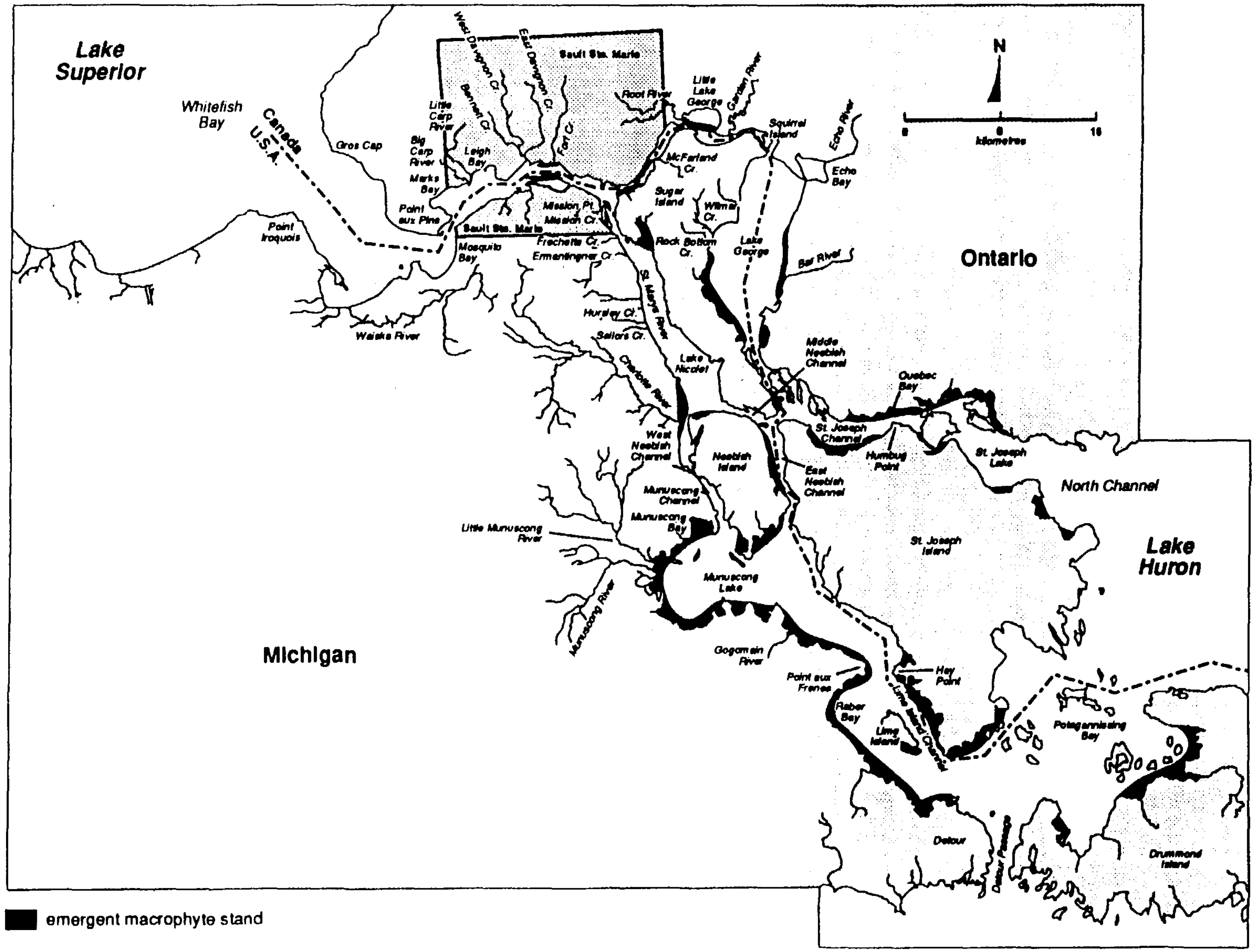
Location	Source	Date	Mean	Trophic Status	Reference
Thunder Bay	Lake Superior	1972-1974 and 1978-1984	138	Oligotrophic	Hopkins (1986)
Thunder Bay	Lake Superior	1979-1984	55	Oligotrophic	Hopkins (1986)
Sault Ste. Marie	Lake Superior	1965-1973	116	Oligotrophic	Michalski (1975)
Sault Ste. Marie	St. Marys River	1965-1982	103	Oligotrophic	Hopkins (1986)
Goderich	Lake Huron	1964-1974	857	Mesotrophic	Michalski (1975)
Grand Bend	Lake Huron	1964-1974	528	Mesotrophic	Michalski (1975)
Sarnia	Lake Huron	1966-1970	686	Mesotrophic	Michalski (1968)
Kingsville	Western Basin, Lake Erie	1966-1967	3,635	Eutrophic	Michalski (1968)
Union (1983)	Western Basin, Lake Erie	1967-1984	3,478	Eutrophic	Hopkins
Wheatly	Central Basin, Lake Erie	1966-1967	544	Mesotrophic	Michalski (1968)
Dunnville (1983)	Eastern Basin, Lake Erie	1969-1984	851	Mesotrophic	Hopkins
Port Dover	Eastern Basin, Lake Erie	1966-1967	438	Mesotrophic	Michalski (1968)
South Peel	Lake Ontario	1970-1984	277	Oligotrophic	Hopkins (1983)
Coburg	Lake Ontario	1966-1967	894	Mesotrophic	Michalski (1968)
Brockville	St. Lawrence River	1965-1967	408	Mesotrophic	Michalski (1968)
Brockville (1981)	St. Lawrence River	1967-1984	383	Mesotrophic	Michalski

Figure 6.40

St. Marys River Remedial Action Plan

Locations of emergent macrophyte stands in the St. Marys River

(from Kauss 1991)



emergent macrophyte stand

6.4.1 Emergent Macrophytes

Emergent vegetation tends to occur along stretches of unoccupied shoreline along the St. Marys River and where sediments consist of clay mixed with variable fractions of sand and silt. Such stands are also particularly well-developed where wind and waves are not a prominent feature of the shoreline environment (Figure 6.40). It is not uncommon for stands of emergent plants to extend uninterrupted along protected shores for distances of 3 km to 5 km. For example a tract of emergents extends 12 km northwards from the Charlotte River.

Some 42 species of emergent and submersed plants have been identified (Appendix 6.5), with biomass dominated by three emergent species: *Scirpus acutus* (hard stem bulrush), *Sparganium eurycarpum* (burr reed), and *Eleocharis smallii* (spike rush), with submersed species occurring as diffuse understories of low biomass (Duffy *et al.*, 1987).

The production and maintenance of emergent macrophytes results from vegetative and clonal growth, typically resulting in monotypic stands. These stands have been a relatively permanent feature of undisturbed shorelines for at least 30 years (Duffy *et al.*, 1987). Of interest is that *Phragmites australis* (common reed) and *Typha latifolia* (common cattail), species which are aggressive and well-established elsewhere in the Great Lakes, are evident only in small stands in drier, shoreward portions of St. Marys River macrophyte beds.

The rootstocks of the three dominant species are present in the substratum year-round. However, the onset of ice-out, warmer temperatures, and increased light during spring results in the generation and rapid growth of new shoots in June and July, followed by rootstocks in August and September. Table 6.14 provides estimates of emergent plant biomass at maturity in the fall, and the distribution of biomass between shoots and rootstocks. The annual cycle of growth coupled with the persistent nature of the rootstocks helps to protect the nearshore sediments from erosion (Duffy *et al.*, 1987).

6.4.2 Submersed Macrophytes

Upstream of the fork of the St. Marys River at Mission Point, and through Lake Nicolet and its downstream reaches, submersed macrophytes spread as meadows of low-growing plants at depths of 2 m to 16 m. They usually occur in broad areas of undeveloped shoreline that are well-protected from wind and wave action, and have silty-clay to sandy-clay substrates and good water clarity (Liston *et al.*, 1986 and Duffy *et al.*, 1987). However, there is virtually no information on submersed macrophytes in Lake George (Liston *et al.*, 1983). Of the 22 species reported for the river, biomass is dominated by the macroalgae *Chara globularis* and *Nitella flexilis* (both charophyles) and the macrophyte *Isoetes riparia* (quillwort).

According to Duffy *et al.* (1987), the submersed macrophytes tend to carpet sediments from the edges of the navigation channel shorewards. The shoreward depth limit of submersed macrophytes is about 2 m. At this depth and greater, the plants are not obvious to the casual observer. More impressive are the scattered clusters of the pondweed, *Potamogeton richardsonii*, which rise to the surface of the water from as deep as 2.5 m. According to Duffy *et al.* (1987), "...Stands of *Isoetes riparia* are virtually monotypic in distribution and are never the deepest stands occurring on a site occupied by submersed plants. Beds of *Isoetes riparia* are confined to depth contours of 2 m to 3.5 m. *Nitella flexilis* occupies the deepest portions of submersed wetlands on suitable sites along the river. Monotypic stands of this species extend to depths of 16 m at the head of the river (Duffy *et al.*, 1987) and 3 m in the reach below Munuscong Lake (Liston *et al.*, 1986). Stands of *Chara globularis* occur in more shallow water than stands of *Nitella flexilis* in reaches of the river where they both occur... *Eleocharis acicularis* (needle rush) and *Myriophyllum tenellum* (water milfoil) are common in these submergent meadows. They are very small plants and contribute little to biomass. In the St. Marys River, the common species of submersed macrophytes are typical of nutrient-poor rather than nutrient-rich environments."

Table 6.14 Biomass in monotypic stands of dominant emergent plants in the St. Marys River at times of peak standing crop (September-October) (Duffy *et al.*, 1987).

Species	Total Live Biomass (g AFDW/m^2)	Total Shoot/Root Biomass Ratio
*Scirpus acutus**		
Low Density	1,340	0.2
Medium Density	1,620	0.5
High Density	3,540	2.2
Sparganium eurycarpum	1,830	0.4
Eleocharis smallii	600	0.7
Phragmites australia	2,000	0.2
Scirpus americanus	320	0.5

*Liston *et al.* (1986) distinguished three densities by assessment of aerial photographs and ground-truth measurements of shoots/m^2 and leaf area/m^2.
AFDW - Ash-free dry weight.

The boundaries, species composition and biomass of the submersed macrophyte beds have remained stable owing to the perennial nature of the dominant species. Biomass of *Isoetes riparia*, one of the dominant species, is relatively constant throughout the growing season of May to September, owing largely to *in situ* mineralization of the over-wintering biomass which occurs as the new shoots develop (Duffy *et al.*, 1987). As reported in Liston *et al.* (1986), submersed plants sampled in the river had a mean peak biomass in the range of 10 g ash-free dry weight (AFDW)/m^2 to 70 g AFDW/m^2, with a mean for all samples between 1979 and 1983 of approximately 36 g AFDW/m^2. This range and mean of seasonal maximum biomass is low relative to that of more fertile lakes and streams which would be in the range of 200 g AFDW/m^2 to 500 g AFDW/m^2 (Wetzel 1983).

6.4.3 Primary Production and Nutrient Cycling

Liston *et al.* (1986) compared the net primary production of phytoplankton, submersed macrophytes and emergent macrophytes in the St. Marys River. They found that this biomass production was concentrated along edges of the river in emergent macrophyte beds and along the bottom in submersed plant communities (Table 6.15) (Duffy *et al.*, 1987). Kauss (1991) summarized important features of nutrient cycling in the St. Marys River, explaining that

> "...there is a tight cycling of nutrients in macrophyte beds, because dead shoot material is rapidly mineralized in spring and partially utilized by new growth (Duffy *et al.*, 1987). Nevertheless, there is some loss of detritus and, to a minor degree, living material to both offshore and downstream areas of the river during ice-out and as a result of wave action. Drifting plant detritus in littoral waters was greater at Frechette Point just downstream of Sault Ste. Marie, Michigan at the inlet to Lake Nicolet than at the head of the river near Whitefish Bay or in the lower reaches of the river (Poe and Edsall 1982 and Jude *et al.*, 1986), and was lower in late winter than in spring. This biomass drift (Figure 6.41) may constitute an important mechanism for the redistribution of nutrients as well as any incorporated or adsorbed contaminants, both within and out of the system (Manny *et al.*, 1990).

Although some of the nutrients released during the decomposition of plant litter are recycled into new plant biomass, much of the remainder supports secondary production of zooplankton and benthic macroinvertebrates. For example, benthic macroinvertebrate increases observed in emergent macrophyte beds occur during the pulses of macrophyte decay in early spring and of periphyton production in late summer. In contrast, the maximum biomass of zooplankton coincides with peaks in water temperature and phytoplankton availability (Duffy *et al.*, 1987)."

Table 6.15 Annual net primary production in the Lake Nicolet reach of the St. Marys River (Duffy *et al.*, 1987).

Community Type	Hectares Occupied	Productivity	
		g AFDW/m^2/yr	tonnes AFDW/yr
Phytoplankton	3,598	5	198
Submersed macrophytes*	2,100	35	735
Emergent macrophytes	298		
Shoots		650	1,937
Periphyton		12	36
Rootstocks		930	2,771

Notes: AFDW–Ash-free dry weight
* Periphyton of submersed macrophytes not included.

6.4.4 Loss of Aquatic Macrophyte Beds

No quantitative information is available on macrophyte losses throughout the AoC. However, there is no question that there have been considerable losses of aquatic vegetation over the years due to the construction of locks, canals, compensating works, hydro facilities, and shoreline dredging and filling.

6.4.5 Effects of Contaminants

There is no specific information on the effects of contaminants on macrophytes and macroalgae in the St. Marys River.

6.4.6 Summary

Some 42 species of submersed and emergent vegetation have been identified in the St. Marys River AoC. Submersed macrophytes exist as meadows or beds of low growing plants at depths of 2 m to 16 m, in areas of the river which have silty-clay or sandy-clay substrate and good water clarity. The species composition, and biomass of these submersed plants have remained stable due to the perennial nature of the dominant species. Biomass is relatively constant throughout the growing season, owing mainly to the *in situ* mineralization of the over-wintering material which occurs as the new shoots develop.

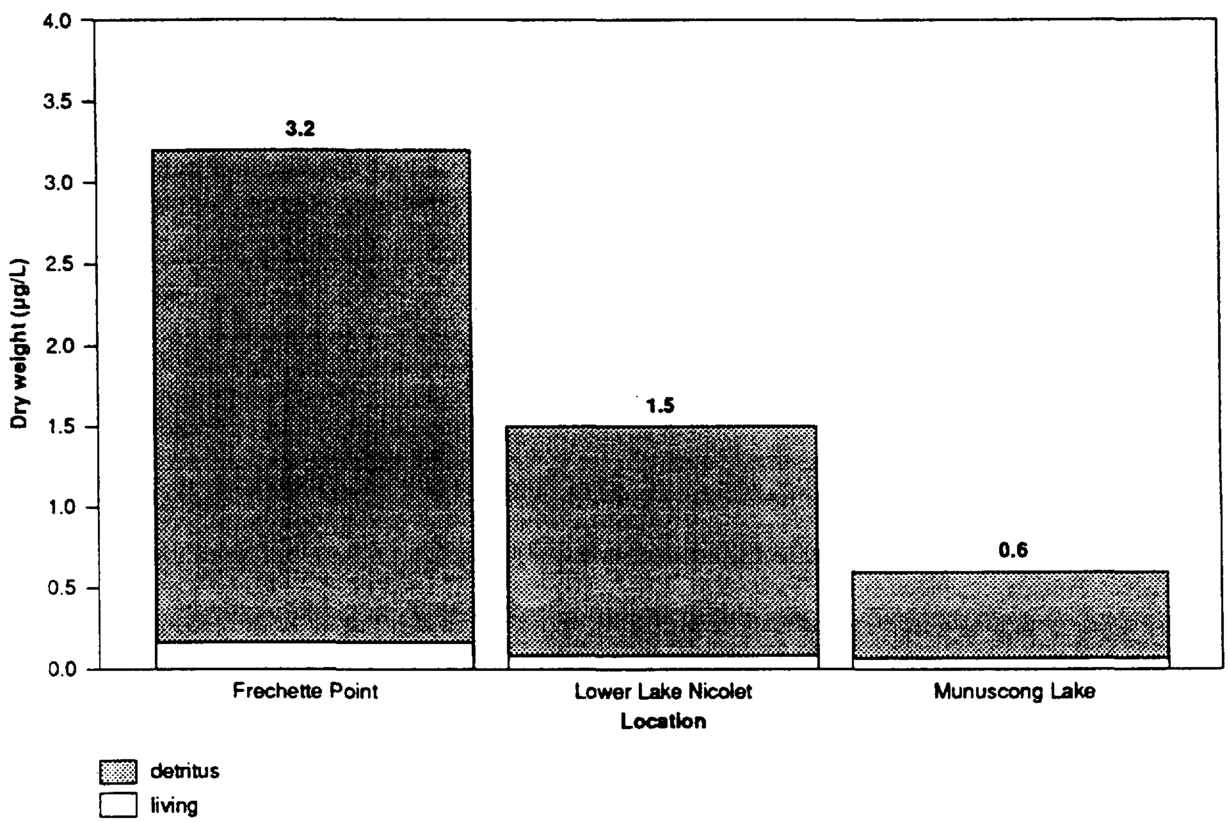
Extensive stands of emergent vegetation occur along unmodified shoreline reaches, particularly those well-protected from wind and wave action. Stands are relatively permanent (30 years and more) owing to their vegetative and clonal growth habitat.

Figure 6.41

St. Marys River Remedial Action Plan

Biomass of drifting aquatic plant material in littoral waters of the St. Marys River, February to March, 1985

(Jude et al. 1986, in Kauss 1991)



Despite the large water area inhabited by phytoplankton, submersed and emergent macrophytes are the most productive per unit area. Further, the shoots and rootstock of emergent macrophytes compose the majority of the macrophyte biomass.

Over the years, some aquatic vegetation has been lost in the AoC by the construction of locks, canals, compensating works, hydro facilities, and shoreline dredging and filling. The extent of this loss is not known.

6.5 ZOOPLANKTON

6.5.1 Background

Zooplankton are important in the aquatic food web because they concentrate energy from phytoplankton biomass into larger particles which are available to fish and other planktivorous feeders. Also, they may form an important link between phytoplankton and plant detritus (see Section 6.4.3). Despite this, little information is available on zooplankton communities in the St. Marys River.

6.5.2 Community Composition

Selgeby (1975) identified approximately 50 species of zooplankton in waters that empty into the river from Whitefish Bay (Appendix 6.6), of which 9 copepods and 3 cladocerans were dominant. Calanoid copepods accounted for 48% of the total number, cyclopoid copepods 39%, and cladocerans the remaining 13%. The winter community consists primarily of adult stages of *Diaptomus sicilis*, *D. ashlandi*, *Limnocalanus macrurus*, immature copepods and *Cyclops bicuspidatus thomasi* (Figure 6.42). During summer, immature calanoids, adult *C. bicuspidatus thomasi* and cladocerans dominate the open waters of the river (Duffy *et al.*, 1987).

Thomas and Liston (1985) reported a similar summer community for the lower river, but much less abundant. However, as explained by Duffy *et al.* (1987), "...Thomas and Liston (1985) utilized a net with 351 μm mesh openings, which would be expected to capture only adult stages or larger individuals, whereas Selgeby (1975) sampled with a 120 μm mesh net." The larger mesh opening would also be expected to shift the observed composition to larger species.

Figure 6.43 shows that the zooplankton of emergent wetlands are almost entirely Cladocera, whereas the pelagic or open-water community is dominated by Cyclopoida and Calanoida. "...Furthermore, the maximum density of zooplankton within emergent wetlands is more than an order of magnitude greater than the maximum densities found in open water. The most abundant species within wetlands were *Chydorus sphaericus* and *Acroperus harpae*, which are both quite small. Common species which are larger and probably more important with respect to standing stock biomass included *Macrocyclops albidis*, *Eurycercus lamellatus*, and *Sida crystallina* as well as Ostracoda. Of the 29 species of zooplankton found in emergent wetland by Duffy (1985), nine were considered rare" (Duffy *et al.*, 1987).

6.5.3 Effects of Contaminants

No investigations have been undertaken to determine contaminant levels in zooplankton, or whether assemblages are being adversely affected within the AoC.

6.5.4 Summary

Zooplankton communities throughout the open waters of the St. Marys River appear to be similar, their numbers being dominated by nine copepods and three cladocerans. In contrast, numbers of zooplankton in the more protected emergent wetlands is more than an order of magnitude greater than maximum densities found in open waters. There is a lack of information on the potential impact of contaminants on the zooplankton community.

Figure 6.42

St. Marys River Remedial Action Plan

Abundance of copepods in open waters of the St. Marys River, November 17, 1971 to November 17, 1972

(from Selgeby 1975)

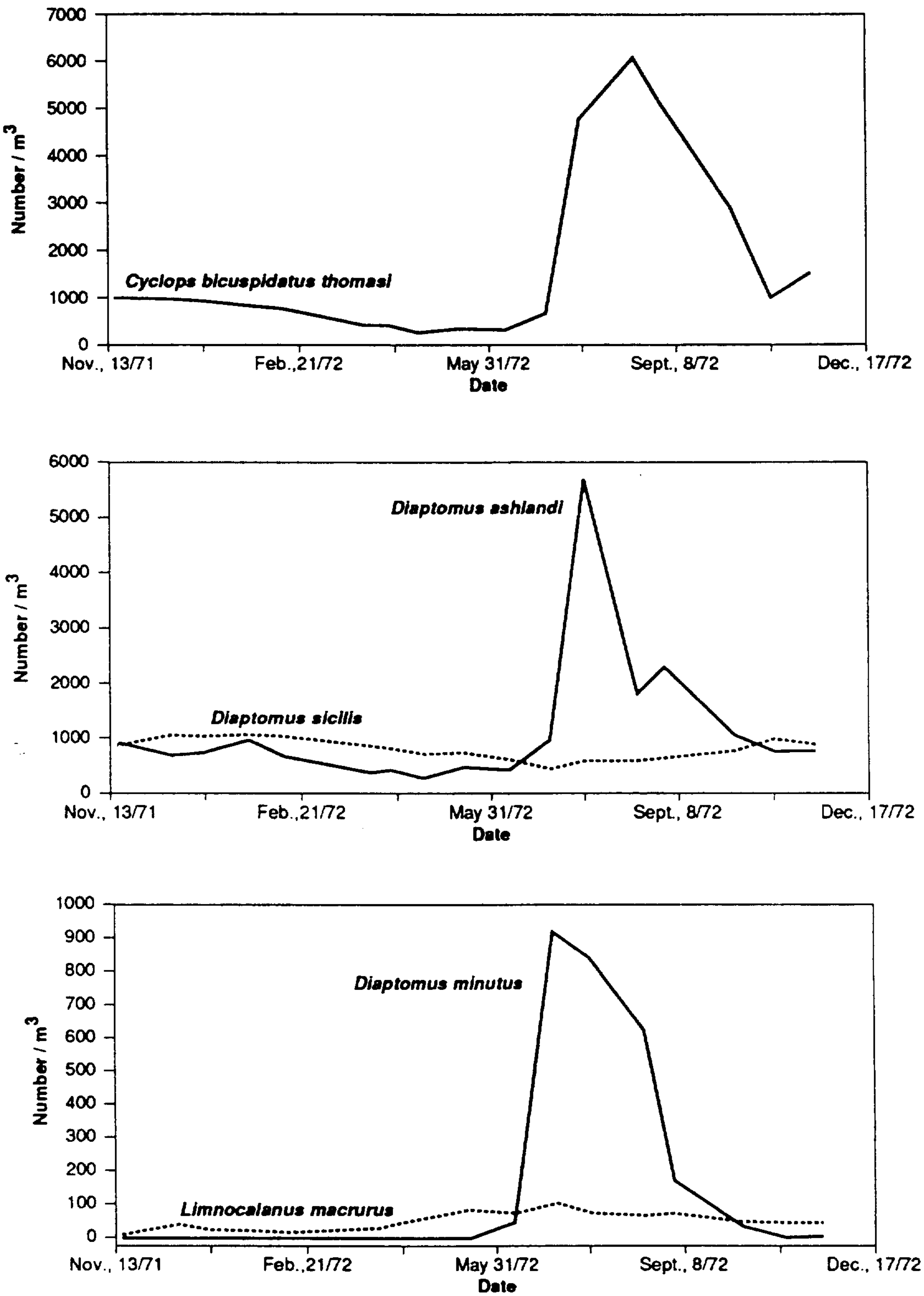
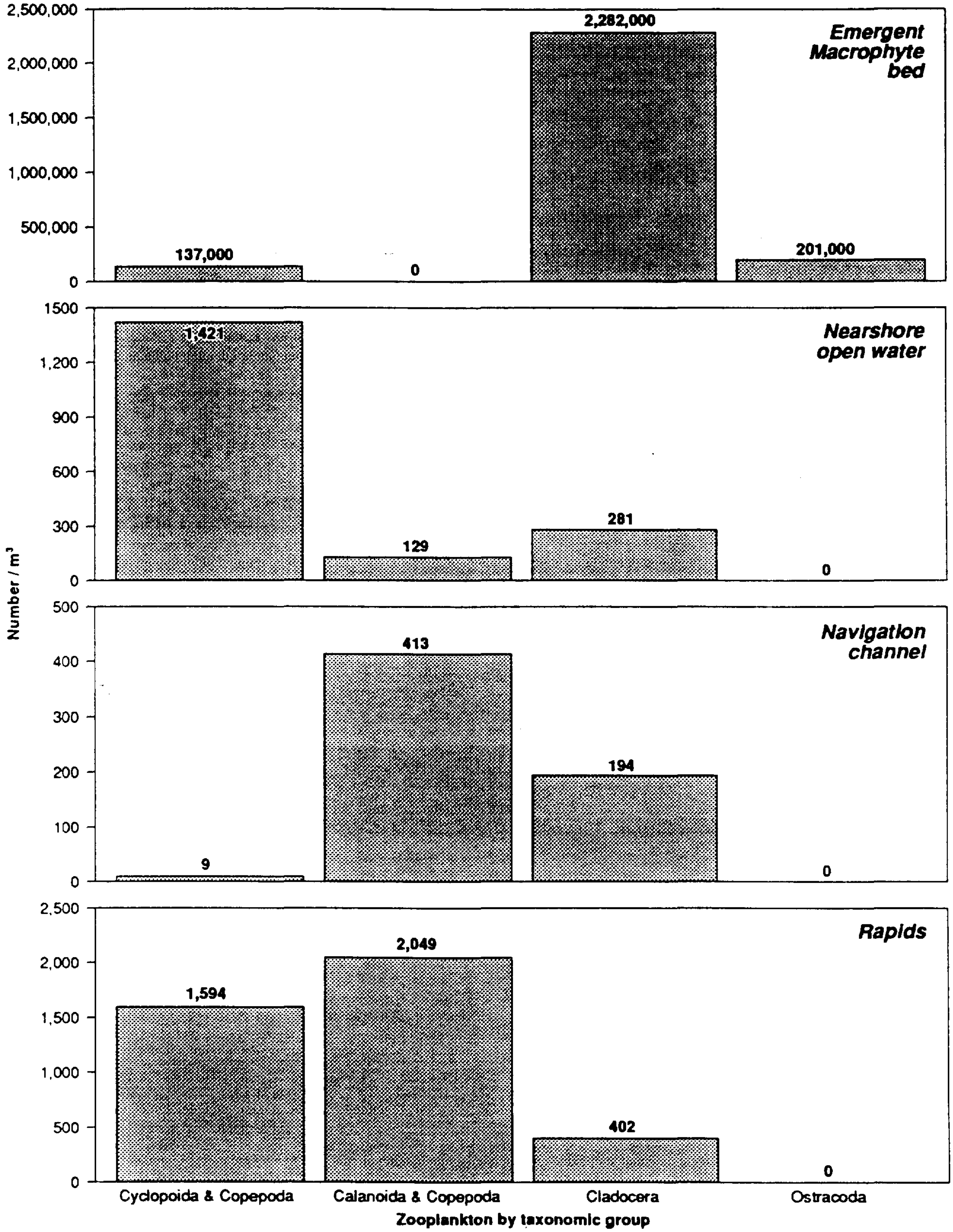


Figure 6.43

St. Marys River Remedial Action Plan

Abundance of zooplankton by taxonomic group in four differect habitats of the St. Marys River

(from Kauss 1991)



6.6 BENTHIC INVERTEBRATES

6.6.1 Background

The bottom-dwelling invertebrates which comprise the benthic macrofauna are those animals which burrow in, cling to, or crawl over the river bottom. Because of their sedentary nature, they respond to a broad range of short and long-term environmental changes. Accordingly, investigations on the distribution and abundance of benthic organisms yield valuable information about the environment which they inhabit. For example, a clean-water community characteristically has a high diversity of different species including pollution-tolerant forms, and has a well-balanced population not dominated by one major group, and a moderate number of organisms. Organically-enriched environments characteristically have a low diversity dominated by pollution-tolerant species. Some insect larvae, notably certain species of midges (*Chironomidae*) and segmented worms (*Tubificidae*), often reach their greatest numbers in organically-enriched sediments. For example, Wright and Tidd (1933) in their classic study of Western Lake Erie, regarded tubificid populations of greater than 5,000/m^2 as indicative of heavy organic enrichment. An environment subjected to a toxic pollutant is characterized by the absence of aquatic life, or very low numbers of the most pollution-tolerant organisms.

Benthic invertebrates are separated by their size into macro-, meio-, and microbenthos. Macroinvertebrates are those which are retained by sieves having screen openings of 250 μm to 500 μm. Meiobenthic species are retained by sieves in the 62 μm to 250 μm range, and microbenthos are those invertebrates which pass through sieves with 62 μm or smaller openings. Little quantitative data exist for the meio- and microbenthos in the St. Marys River however, nematodes, ostracods, and *Hydra* sp. are likely the most abundant components of these two groups (Duffy 1985, Duffy *et al.*, 1987 and Burt *et al.*, 1988). Other meiobenthos include cyclopoid and harpactacoid copepods, cladocerans, tardigrades, and Nemertinea (Hiltunen 1979, Poe *et al.*, 1980 and Duffy 1985).

6.6.2 Community Composition

Due to ease of sampling, considerable information is available on benthic macroinvertebrates, in contrast to the micro- and meiobenthos. As pointed out by Edsall *et al.* (1988), nearly 30 years separate the first published study on St. Marys River benthos (Goodrich and Van der Schalie, 1939) from the second (Veal, 1968), and most of the published information (Hamdy *et al.*, 1978, Hiltunen 1979, Poe *et al.*, 1980, Liston *et al.*, 1980 and 1986, Poe and Edsall 1982, Liston *et al.*, 1983 and 1986, Hiltunen and Schloesser 1983, Koshinsky and Edwards 1983, McKee *et al.*, 1984, Duffy 1985, Duffy *et al.*; 1987, Persaud *et al.*, 1987, and Burt *et al.*, 1988) has been produced in the last ten years. However, comparisons are difficult, since the use of sieves of different size mesh openings can show shifts in species composition and abundance owing to different retention of smaller organisms (Nalepa and Robertson, 1981). Apparent changes in species composition or abundance can occur if sampling occurs at different times of the year in different surveys. As well, sampling stations have been either increased, decreased, or shifted in location depending on the objectives of the investigation. Other potential problems of data comparison include differences in sampling gear (airlift sampler versus a Ponar grab) and sorting efficiency (Burt *et al.*, 1988).

The St. Marys River community is diverse, with 303 individual taxa identified (Appendix 6.7). Community composition is influenced mainly by substrate, depth, water temperature, currents and wave action, the presence and density of aquatic vegetation, and in certain areas, point source pollution (Duffy *et al.*, 1987 and Burt *et al.*, 1988). Duffy *et al.* (1987) recognized four distinct habitats: soft substrates, emergent macrophytes, rapids, and the shipping channel. Chironomids and oligochaetes are numerically abundant in all habitats, consisting of 60% to 90% of the benthos at a given site (Edwards *et al.*, 1989). However, Ephemeroptera, particularly the burrowing mayflies, *Hexagenia limbata* and *Ephemera simulans*, (the former an indicator of mesotrophic conditions), and Trichoptera (caddisflies) are also important in some habitats (Table 6.16).

Table 6.16 Benthic macroinvertebrates characteristic (occurring at >50% of stations) of different habitats in the St. Marys River (Duffy *et al.*, 1987).

	Habitat			
	Emergent Macrophytes	Soft Bottom	Shipping Channel	Rapids
Oligochaeta				
Ophidonais serpentina		X		
Limnodrilus sp.		X		
Peloscolex ferox		X		
Stylaria fossularis	X			
Polychaeta				
Manayunkia speciosa	X			
Amphipoda				
Gammarus fasciatus	X			
Hyalella azteca	X	X		
Hydracarina	X	X	X	X
Ephemeroptera				
Baetis sp.	X			
Caenis sp.	X			
Ephemera simulans	X			
Hexagenia limbata		X		
Stenonema tripunctatum				X
Leptophlebia sp.				X
Trichoptera				
Cheumatopsyche sp.				X
Helicopsyche borealis				X
Hydropsyche bifida				X
Polycentropus sp.	X			
Hemiptera				
Corixidae	X			
Coleoptera				
Donacia sp.	X			
Diptera				
Ceratopogonidae	X	X		
Cryptochironomus sp.	X	X		
Dicrotendipes sp.		X		
Epoicocladius sp.		X		
Larsia sp.	X	X	X	X
Paratanytarsus sp.	X	X		
Polypedilum sp.	X	X		
Procladius sp.	X	X		
Psectrocladius sp.	X			
Stictochironomus sp.	X	X		
Tanytarsus sp.	X	X		
Simulium sp.				X
Mollusca				
Amnicola sp.	X	X		
Physa sp.		X		
Pisidium sp.	X	X		
Sphaerium sp.		X		

The zebra mussel, *dreissena polymorpha (pallas)*, was discovered in June, 1988 in Lake St. Clair. Due to the potential impact on aquatic systems and the ability for widespread distribution, the zebra mussel has become a focus of study in the Great Lakes Basin. The 1990 distribution of zebra mussels ranged from the southern areas of Lake Ontario to the head of the St. Clair River (Griffiths *et al.*, 1991). Isolated populations have been observed in Lake Michigan, Saginaw Bay, and Port Elgin on Lake Huron (Kraft 1990). To date there have been no reports of zebra mussels in the St. Marys River.

6.6.2.1 Soft Substrate Benthos

The benthic invertebrate community of soft sediments is dominated both numerically and in terms of taxonomic diversity by chironomid larvae and oligochaetes. Of the chironomids, *Larsia* sp. is ubiquitous with another 7 genera being common in two or more parts of the river (Table 6.16). Chironomids make up the greatest proportion of the total benthic community near the head of the river, but they are most abundant numerically in the middle reaches of the river (Table 6.17). In contrast, oligochaetes generally are found in progressively larger proportions from the upper to the lower river (Table 6.17). However, organic enrichment in the upper river near Sault Ste. Marie, Ontario resulted in large populations of certain organic pollution-tolerant species of oligochaetes such as *Limnodrilus hoffmeisteri*. In addition to Chironomidae and Oligochaeta, other taxa such as Ephemeroptera, Amphipoda, and Mollusca, are common or abundant and contribute substantially to the numbers (Table 6.17).

Because of their central role in trophic interactions, Ephemeroptera may be the most important group of benthic invertebrates in the St. Marys River (Duffy *et al.*, 1987). Seventeen species or genera have been collected from the river. Nymphs of two mayfly species, *Hexagenia limbata* and *Ephemera simulans*, are particularly abundant in areas of soft substrate. Nymphs of both species grow quite large relative to most aquatic invertebrates and, with the more abundant *Hexagenia limbata* having a 2-year life cycle and ranging in size from 1 to 30 mm in the St. Marys River, can represent a considerable proportion of the standing stock or biomass (Liston *et al.*, 1983, Schloesser and Hiltunen 1985). Throughout its range, *Hexagenia limbata* is most abundant in depositional environments where fine sediments predominate, while species of *Ephemera* are reported to prefer substrates of slightly coarser sediments (Hunt 1953, Erickson 1968). The distribution of both species of mayflies in the St. Marys River generally supports these observations. *Hexagenia limbata* is most abundant in parts of Lakes George and Nicolet and in the lower river where fine sediments occur, while *Ephemera simulans* is more common in the coarser sediments of Lake Nicolet and the upper river (Hiltunen 1979, Liston *et al.*, 1983 and 1986). Tricoptera are almost never numerically abundant, but are one of the most taxonomically diverse benthic groups in the St. Marys River.

6.6.2.2 Emergent Macrophytes Benthos

The benthic macroinvertebrate community of emergent macrophytes is also taxonomically diverse: of the 171 taxa recorded from this habitat, 118 are aquatic insects. In term of numbers, chironomids and oligochaetes dominate the community (Duffy *et al.*, 1987), just as they do in soft-bottom habitats. Oligochaetes represent a greater proportion of the total fauna in the southern portion of the river than in the middle or upper river. Also, there are several taxa which are dependent on and occur only or primarily in this habitat. For example, "...larvae of the beetle *Donacia* sp. are phytophagous (plant-eating), and develop within the stems of the emergent macrophyte *Sparganium eurycarpum*. While less common, larvae of the moth *Belluia* sp. have similar habitat requirements, but develop in *Scirpus* sp. stems. The mayfly *Siphloplecton* sp. occurs along the wetland face. It is an active swimmer about which little is known since it is infrequently captured by conventional benthic sampling techniques. Many of the *Hemiptera* and certain species of Odonata are restricted to more dense stands of macrophytes" (Duffy *et al.*, 1987).

Table 6.17 Average number of benthic macroinvertebrates/m^2 and percent of the total represented by major taxonomic groups collected from offshore stations in the St. Marys River during 1983 (Duffy et al., 1987).

Taxa	Location						
	IWB	LN	MNC	NML	SML	PAF	RB
Oligochaeta	14	17	21	21	29	41	35
Polychaeta	0	7	<1	2	2	1	4
Amphipoda	2	5	2	<1	5	3	2
Isopoda	<1	3	2	1	1	<1	0
Ceratopogonidae	3	1	3	2	5	1	0
Chironomidae	73	64	67	67	52	44	48
Ephemeroptera	3	3	3	2	6	6	6
Trichoptera	<1	<1	<1	<1	<1	<1	<1
Gastropoda	1	1	<1	2	2	<1	<1
Pelecypoda	1	<1	<1	<1	1	2	2
Other	3	<1	1	2	2	2	1
Average number/m^2	9,879	18,710	20,846	13,895	8,613	9,682	7,381

Initials correspond to the following areas of the river:

IWB - Izaac Walton Bay (Mosquito Bay)
LN - Lake Nicolet
MNC - Middle Neebish Channel
NML - North Munuscong Lake
SML - South Munuscong Lake
PAF - Pointe aux Frenes
RB - Raber Bay

6.6.2.3 Rapids Benthos

The benthic macroinvertebrate community of the St. Marys Rapids and Lake Nicolet Rapids is typical of those found elsewhere in rapids or rocky streams (Koshinsky and Edwards 1983, Duffy *et al.*, 1987), but differs substantially from communities found in other portions of the river (Duffy *et al.*, 1987). Trichoptera larvae, particularly two genera of net-spinning caddisflies of the family Hydropsychidae (*Hydropsyche bifida* and *Cheumatopsyche* sp.), are more abundant in the rapids than elsewhere in the river. A study was performed in November of 1973 on the benthic organisms of the dewatered area in the Ontario section of the rapids. In the St. Marys Rapids, *Hydropsyche bifida* is the predominant taxon, comprising about 80% of the *Hydropsychidae* (Koshinsky and Edwards 1983). In the Lake Nicolet Rapids, *Cheumatopsyche* sp. are predominant and comprise 95% of the Hydropsychidae (Duffy *et al.*, 1987). Koshinsky and Edwards (1983) attributed the preponderance of *Hydropsyche bifida* in the St. Marys Rapids to its affinity for faster flowing water. *Cheumatopsyche* sp. are known to inhabit slower flowing and warmer water than *Hydropsyche* sp. (Wiggins 1979). These observations are consistent with the distribution of these two taxa in the St. Marys River (Duffy *et al.*, 1987).

6.6.2.4 Shipping Channel Benthos

The navigation channels in the St. Marys River do not provide good habitat for benthic invertebrates (Duffy *et al.*, 1987, Liston *et al.*, 1980 and 1986). Vessel-induced turbulence and the removal of soft substrates by dredging are probably responsible for the impoverished communities. Only Oligochaeta and Chironomidae are common, and both diversity and density are much lower in the shipping channels than in all other habitats. The only exception is at the junction of the Middle Neebish Channel and Munuscong Lake and in the southern portion of the river below Munuscong Lake where depositional materials tend to settle out. Here, the polychaete worm *Manayunkia speciosa* and oligochaetes are sometimes abundant.

6.6.3 Benthic Production

Estimates of benthic macroinvertebrate production for several areas of the St. Marys River are quite similar between habitats on a per unit area basis (Liston *et al.*, 1983, Duffy 1985 and Duffy *et al.*, 1987). In soft-bottomed offshore areas of Lake George, *Hexagenia limbata* and fingernail clams (Sphaeriidae) contribute over half of the annual production, while in Lake Nicolet, most of the total production is contributed by chironomids, oligochaetes and the amphipod *Hyalella azteca* (Table 6.18). On an areal basis, annual benthic invertebrate production is greater in soft-bottom areas than in emergent macrophytes or rapids areas of the river (Duffy *et al.*, 1987).

Table 6.18 Estimated benthic macroinvertebrate production (mg dry weight/m^2/year) in the emergent-littoral zone and the 3 m depth contour of Lakes George and Nicolet and in the Lake Nicolet Rapids (Duffy *et al.*, 1987).

Taxon	Lake Nicolet			Lake George	
	Rapids	Littoral	Offshore	Littoral	Offshore
Ephemeroptera					
Ameletus sp.		10		166	
Caenis sp.		1,155	80	1,284	132
Ephemera simulians		20	774	11	199
Ephemerella sp.		3	69	43	
Hexagenia limbata		47	762	95	6,206
Leptophlebia sp.	3,770	7	26	222	181
Stenonema tripunctatum	2,270				
Trichoptera					
Ceraclea sp.		29	3		
Cheumatopsyche sp.	3,003				
Grammotaulus sp.		210			
Phryganea sp.		38			263
Phylocentropus sp.			14	12	64
Polycentropus sp.		280	229	97	186
Trianodes sp.		38	38	11	38
Other Trichoptera		53	27	39	39
Hemiptera					
Singara cornuta		1,368	19	43	
Ondonata					
Aeshna canadensis				4,767	
Arigomphus sp.				2,633	
Enallagma boreale		127		428	
Lestes disjunctus		134			
Libellula sp.				176	

Table 6.18 (Cont'd)

Taxon	Lake Nicolet			Lake George	
	Rapids	Littoral	Offshore	Littoral	Offshore
Diptera					
Chironomidae:					
Ablabesmyia sp.		90	1,069	412	
Cryptochironomus sp.		537	466	331	552
Larsia sp.		596	299	488	158
Paratanytarsus sp.		1,200	305	35	
Polypedilum sp.		1,520	2,205	839	1,197
Procladius sp.		1,192	1,045	594	659
Psectrocladius sp.		155	50	274	25
Stictochironomus sp.		452	55	95	10
Other Chironomidae	3,330	2,923	704	2,900	280
Simulidae					
Simuliam sp.	112	6	8		
Amphipoda					
Hyalella azteca		2,250	2,228	812	912
Gammarus fasciatus		354	85	111	129
Isopoda					
Asellus intermedia		2,777	25	645	117
Lirceus sp.		1,008	984	306	792
Decapoda					
Orconectes propinqus	11,200				
Gastropoda		123	237	108	406
Pelecypoda					
Spaeriidae		144	397	53	4,347
Oligocheata					
Stylaria fossularis		2,045			
Other Oligocheata		1,464	2,003	291	1,468
Miscellaneous Taxa		2,336	563	1,800	857
Totals:	23,683	24,682	14,464	20,020	18,846

6.6.4 Effects of Contaminants

The benthic macroinvertebrates on the Michigan (Sault Ste.Marie) side of the AoC are generally indicative of clean water conditions. However, adjacent to and downstream from Sault Ste. Marie, Ontario, discharges of organic and inorganic contaminants have significantly altered the benthic invertebrate community structure of soft-bottom areas. Surveys in 1968 and 1973 demonstrated zones of severe impairment from pulp and paper, steel mill and municipal WPCP discharges (Figure 6.44). Sediments along the Sault Ste. Marie, Ontario side were dominated by oligochaetes such as *Tubifex tubifex* and *Limnodrilus hoffmeisteri* which are tolerant of organic pollution. Also, the burrowing mayfly *Hexagenia limbata* was virtually absent from these areas as far downstream as Lake George, owing to the intolerance of this species to oil contamination.

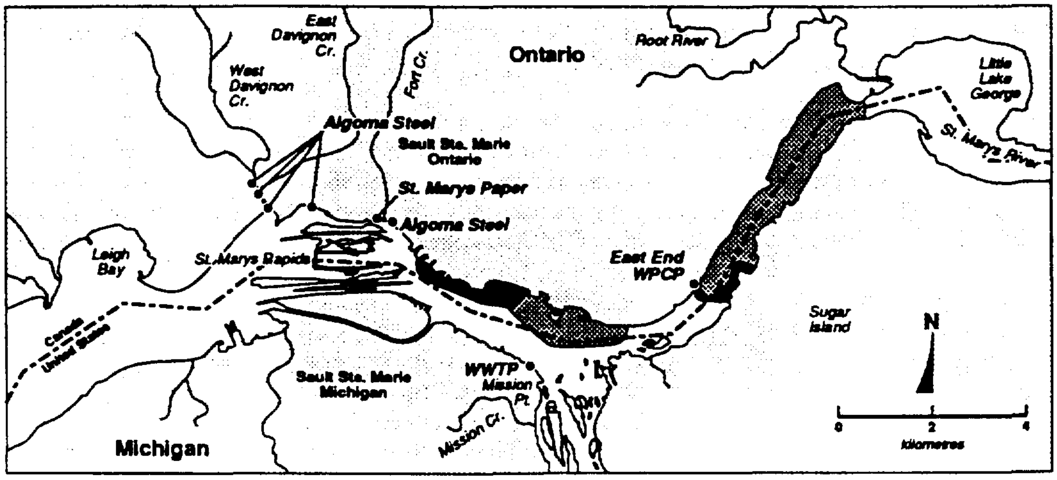
Figure 6.44

St. Marys River Remedial Action Plan

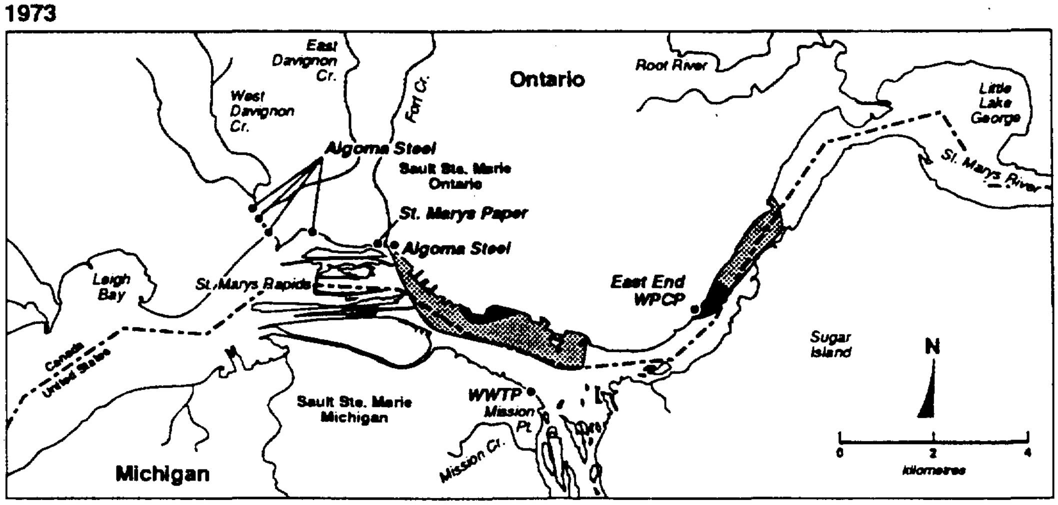
Distribution and zones of impairment of benthic macroinvertebrates in the St. Marys River in 1968, 1973 and 1983

(from Burt et al. 1988)

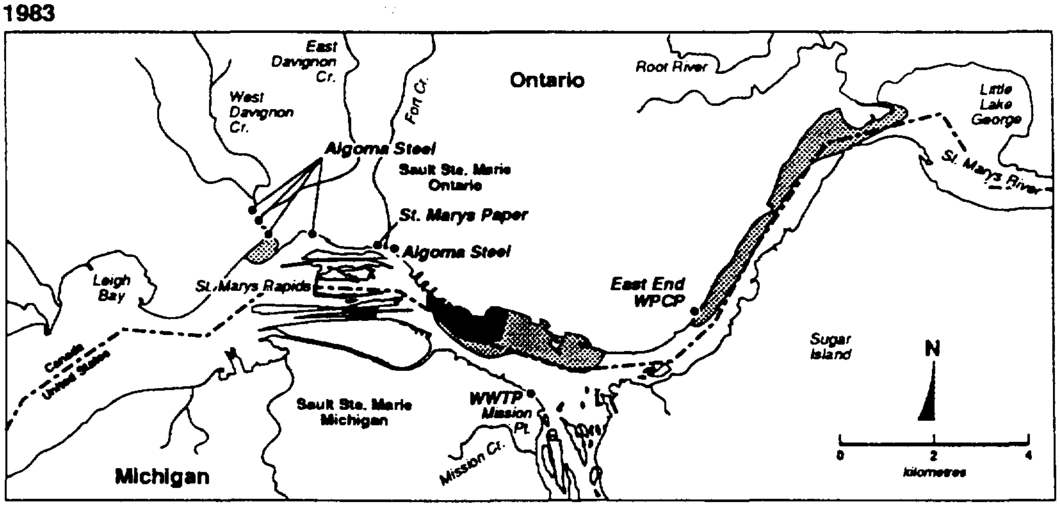
1968



1973



1983



Zones of impairment

- severe
- moderate
- unimpaired

• point source discharge location

Hamdy *et al.* (1978) identified zones of severe or strong impairment adjacent to and downstream of the Algoma Steel, St. Marys Paper and Sault Ste. Marie East End WPCP discharges. Results indicated that between 1967 and 1974 to 1975, the occurrence of oil in the substrate of the Lake George Channel had advanced from 16 km to 30 km downstream. The absence or low densities of nymphs generally coincided with the presence of visible oil in the sediments (Figure 6.45). In addition, the complete absence of larvae of the genus *Simulium*, the biting black fly was noted.

In the study conducted by OMOE in 1983 which examined the impact of changing hydrological conditions due to reconstruction of the Great Lakes Power Corporation generating station and ongoing pollution abatement programs at Algoma Steel, benthic communities were found to be similar to those of 1968 and 1973 (McKee *et al.*, 1984). Zones of severe or moderate benthic impairment were still found adjacent to and downstream from the paper and steel mills and WPCP discharges (Figure 6.44). However, the severely impacted community characterized by high densities of *Tubifex tubifex* and *Limnodrilus hoffmeisteri* observed in 1968 and 1973 (Figure 6.44) was less pronounced in 1983, and this zone was confined to an area immediately downstream from the Rapids, along the Ontario shoreline. McKee *et al.* (1984) suggested that reduced industrial contaminant loadings appeared to have resulted in the minor improvement. There is impact owing to transboundary movement of pollutants from Ontario to Michigan waters. Figure 6.44 shows that in 1968 benthic macroinvertebrates were impaired throughout the Lake George Channel in both Ontario and Michigan waters. By 1983, the zones of impairment have been reduced and occur in Michigan waters in the Lake George Channel at the entrance to Little Lake George and in the centre of the river downstream of the locks (Figure 6.44). Figure 6.46 show further reductions in the zones of impairment in 1986, and impaired zone in the northern part of Lake George straddles the Canada-U.S border.

Because the 1983 survey was less extensive at downstream areas than those of earlier years, with little or no sampling in Lake George, Little Lake George or Lake Nicolet, or upstream of Leigh Bay, additional sampling was undertaken by the OMOE in 1985 to fill these data gaps. To better distinguish zones of impact and sediment effect levels, cluster analysis was performed on the 1985 data using various physical, chemical, and biological components of the benthic system. Seven major clusters were distinguished based on similarities in species composition, from which four zones of pollution impairment were identified (Table 6.19 and Figure 6.46). Table 6.19 shows that there is overlap between the zones of impairment particularly with visible oil. It should be noted that the presence of visible oil is meaningless with respect to the classification unless one knows exactly what kind of oil is present. Details of the impairment zones are as follows:

Severe:
This zone was found in the Algoma Slip and in embayments downstream from industrial and municipal discharges along the Ontario shoreline. It is characterized by extreme tubificid dominance, pollution-tolerant chironomids, low numbers of taxa and high total densities or communities having either very low total densities and low numbers of taxa and/or high densities of nematodes with few other taxa.

Moderate:
This zone, about 500 m in width, was confined mainly to the Ontario shoreline, and extended 4 km downstream from the industrial and municipal discharges and was also identified in Little Lake George and Lake George. Tubificid dominance, with high densities of nematodes and chironomids tolerant of organic enrichment are the major characteristics of this zone. Also, polychaete worms are absent and numbers of taxa are reduced, while total densities are high.

Slight:
Some recovery is evident with increased distance from industrial and municipal discharges; however, complete recovery is not evident until lower Lake George. Nematodes and polychaetes dominate with moderate densities of tubificids and some non-tolerant groups.

Unimpaired:
This zone occurs in the upper reaches of the river and along the Michigan shoreline. Communities tend towards chironomid dominance, with several non-tolerant groups such as ephemeropterans and trichopterans, with low tubificid densities, and numbers of taxa.

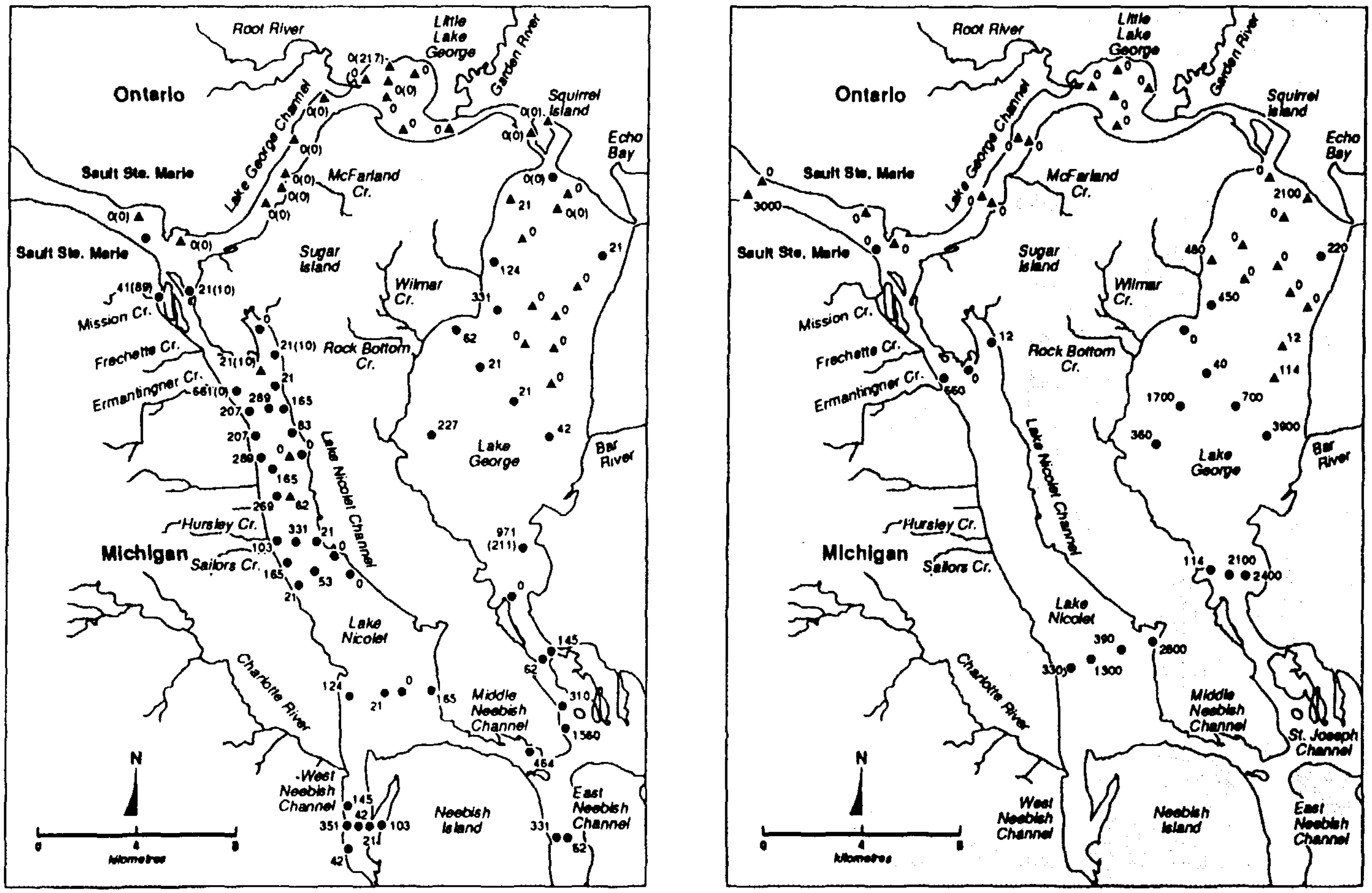
Figure 6.45

St. Marys River Remedial Action Plan

Distribution of Hexagenia nymphs and visible oil in the St. Marys River sediments in 1975 and 1985

(Hiltunen and Schloesser 1983 and Burt et al. 1988, respectivley)

1975 **1985**



63(276) — density of *Hexagenia* nymphs (number / m²); densities collected by OWRC in 1967

● sampling location of *Hexagenia* nymphs with no visible oil in the substrate

▲ sampling location of *Hexagenia* nymphs with visible oil in the substrate

Table 6.19 Characteristics of benthic macroinvertebrate community zones in the St. Marys River, 1985 (Burt *et al.*, 1988).

	Zones of Impairment (see Figure 6.46)			
	Unimpaired	**Slight**	**Moderate**	**Severe**
Common Taxa	Immat. tubificids without chaetae Nematoda* *Procladius* *Bezzia* *Manayunkia** *Spirosperma* *Cricotopus* *Pisidium* Chironomidae* *Polypedilum* *Chironomus* *Helisoma* *Amnicola limosa* *Hyalella* Hydracarina *Valvata sincera*	Immat. tubificids* without chaetae Nematoda* *Manayunkia** Nemertea *Stylodrilus* *Pisidium* *Spirosperma* Immat. tubificids with chaetae	Immat. tubificids* without chaetae Nematoda* *Nais variabilis*	Immat. tubificids* without chaetae Nematoda* Chironomidae*
Mean Number Taxa	27-40	23	15	12
Mean Total Density (No/m^2)	56,000-201,000	192,000	259,000	71,000
Substrate	Variable Silty - Coarse Sand	Coarse Sand with or without Silt	Organic Silt	Silt
Water Depth (m)	1-13.7	2.5-14	1-16	1.5-8.5
Macrophytes	Variable	Absent or Sparse	Variable	Usually Absent
Visible Oil	Absent - Very Strong	Absent - Very Strong	Slight - Very Strong	Absent - Very Strong
Current	None - Moderate	Absent - Moderate	None	None - Strong

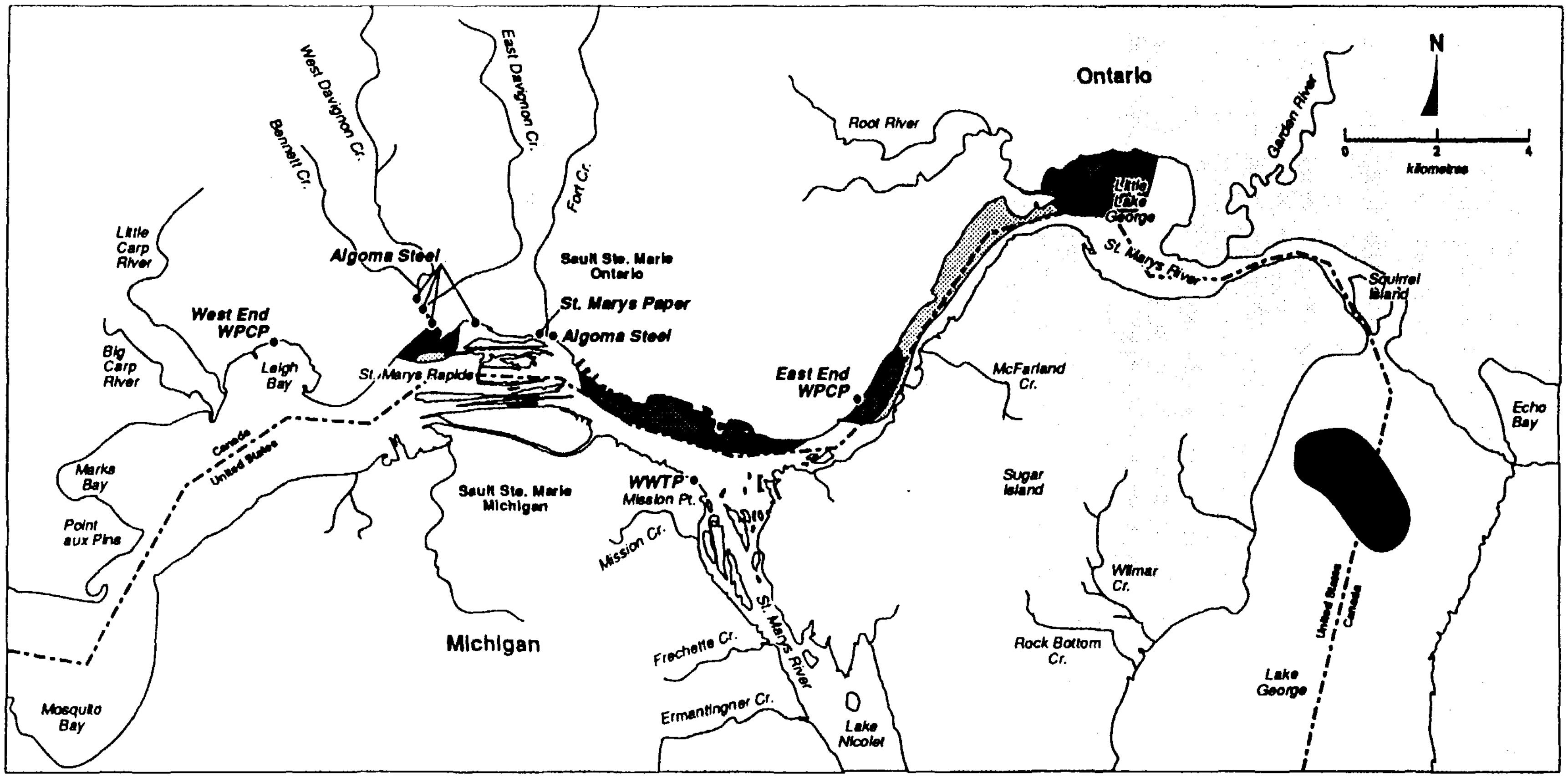
* Dominant taxa

Figure 6.46

St. Marys River Remedial Action Plan

Distribution and zones of impairment of benthic macroinvertebrates in the St. Marys River in 1985

(from Burt et al. 1988)



1985 zone of impairment

- severe
- moderate
- slight
- unimpaired
- • point source discharge location

Some recovery of the benthic communities was observed with increasing distance downstream of contaminant discharges. Nevertheless, the combined effect of effluent from all upstream sources was still evident in the upper, deeper portion of Lake George in 1985 as a zone of moderate impairment (Figure 6.46). Complete recovery (unimpaired communities) was not evident until the lower section of Lake George (Burt *et al.*, 1988).

6.6.5 Sediment Quality - Benthic Macroinvertebrate Community Relationships

Burt *et al.* (1988) derived a bottom faunal community index to examine the sediment quality characteristics of St. Marys River benthic communities in 1985. Of the five species guilds identified, the dominance index of Guild B was the best indicator of toxic contaminants (both metals and pesticides) and was also defined by the two most abundant indicator taxa (pollution-tolerant nematodes and immature tubificids without setae, most likely *Limnodrilus* spp.). The best multivariate equation for predicting the dominance of the nematode/immature tubificid community from sediment characteristics included significant positive contributions from mercury, heptachlor epoxide, clay and total organic carbon. High concentrations of these constituents tended to increase the predicted index. The highest index values for this guild occurred in the vicinity of the Algoma Slip and the East End WPCP, indicative of severe impact. Zones of moderate impact were also apparent in a depositional area downstream of the St. Marys Rapids on the Ontario side, downstream of the East End WPCP into Little Lake George, and in a deep water depositional area of Lake George near the inlet.

Of importance is that the zones of impairment defined by the community index approach closely resembled the zones of impairment earlier described and shown in Figures 6.44 and 6.46. However, the impact zones defined by the dominance index suggested a slightly greater degree and extent of impact in Little Lake George and Lake George than shown by the station cluster distribution technique.

The similarity between zones of impact derived from the station cluster patterns and dominance index analyses clearly strengthen the position that pollution-tolerant benthic communities are continuing to persist downstream of the Algoma Steel, St. Marys Paper and East End WPCP discharges, extending downstream along the Ontario shoreline as far as upper Lake George (Burt *et al.*, 1988).

Benthic macroinvertebrates were also identified from 2 cm thick sections from the upper 20 cm of sediment cores collected in the St. Marys River by as part of OMOE's MISA initiative in 1987 (Figure 6.47). In contrast to the foregoing, the abundance and diversity of species was generally higher at stations downstream of major Ontario point sources (stations 155, 157 and 169) than in Little Lake George or at the upstream station. Abundance and diversity generally decreased with increasing depth in cores. However, benthic communities downstream of major point sources were characterized by high numbers of oligochaetes and were correlated with high concentrations of metals, PAHs, phosphorus and organic carbon, whereas the upstream station (station 52) was characterized by pollution-intolerant chironomid species that were correlated with low levels of the above contaminants and elevated levels of nitrogen (Pope 1990).

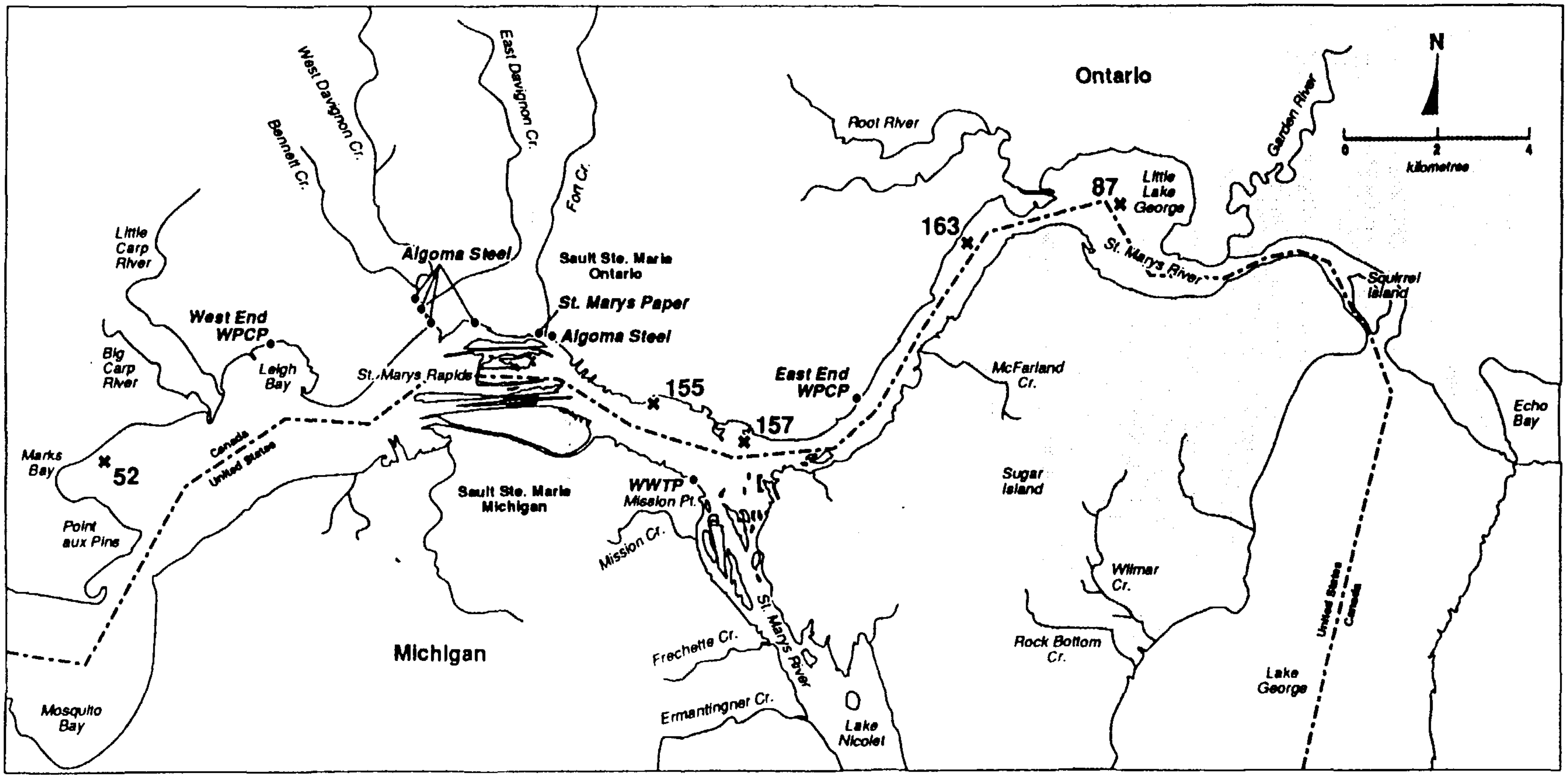
Sediment samples collected along with benthic invertebrate samples in 1985 were contaminated by oily substances at most stations between the East End WPCP and upper Lake George. This does not imply that the WPCP is the major source of the oil, because oil also occurred in abundance at stations upstream of the WPCP. The results of the 1985 survey suggested that the extent of sediment contamination by oil in the Lake George Channel has not changed from that observed in 1975 (Figure 6.45). Visible oil was not observed in the Lake Nicolet Channel sediments in 1985, and was very limited in distribution in this area during the 1975 survey.

The distribution of *Hexagenia limbata* nymphs in 1985 remained similar to that observed in 1975 (Figure 6.45). In 1985, *Hexagenia limbata* was absent from sediments from 27 of 32 stations in the St. Marys River, Lake Nicolet, Lake George Channel, Little Lake George and Lake George that contained even slight

Figure 6.47

St. Marys River Remedial Action Plan

St. Marys River sediment core sampling locations, 1987



✖ sediment core sampling location

• point source discharge location

amounts of visible oil. In contrast, at the remaining 19 stations where visible oil was absent, 16 had *Hexagenia limbata* populations present (Burt *et al.*, 1988). At two of three remaining stations where *Hexagenia limbata* was absent, the bottom substrate was primarily sand, a substrate which is not usually inhabited by *Hexagenia limbata* (Edwards *et al.*, 1989).

A joint U.S.EPA/FWS study of the entire St. Marys River in 1985 also found that, in general, the densities of *Hexagenia limbata* nymphs were significantly lower at stations where sediments contained visible oil (11 organisms/m^2) than at stations without oil (249 organisms/m^2). The visible oil is probably the lighter, more water-soluble and more toxic fractions of oils spilled (or discharged) into the river over the years from three main sources: steel plant rolling mills, chemical plant oil separators and heavy fuel or bilge oils from passing vessels (Schloesser *et al.* 1991, in press).

Edsall *et al.* (1991 in press) found that dry weight production of *Hexagenia limbata* nymphs per unit area during the period April to October, 1986 at an upper Lake George station with sediment concentrations of oil and grease, cyanide, cadmium, chromium, copper, nickel and zinc above U.S.EPA and OMOE guidelines for the disposal of dredged material was only about 12% of that at stations where contaminant levels were below the guidelines (Figure 6.48). It is generally believed that, because of their respiratory gills, *Hexagenia* nymphs are particularly sensitive to the presence of oils in sediments.

6.6.6 Contaminants in Benthic Invertebrates

6.6.6.1 Oligochaetes and Mayflies

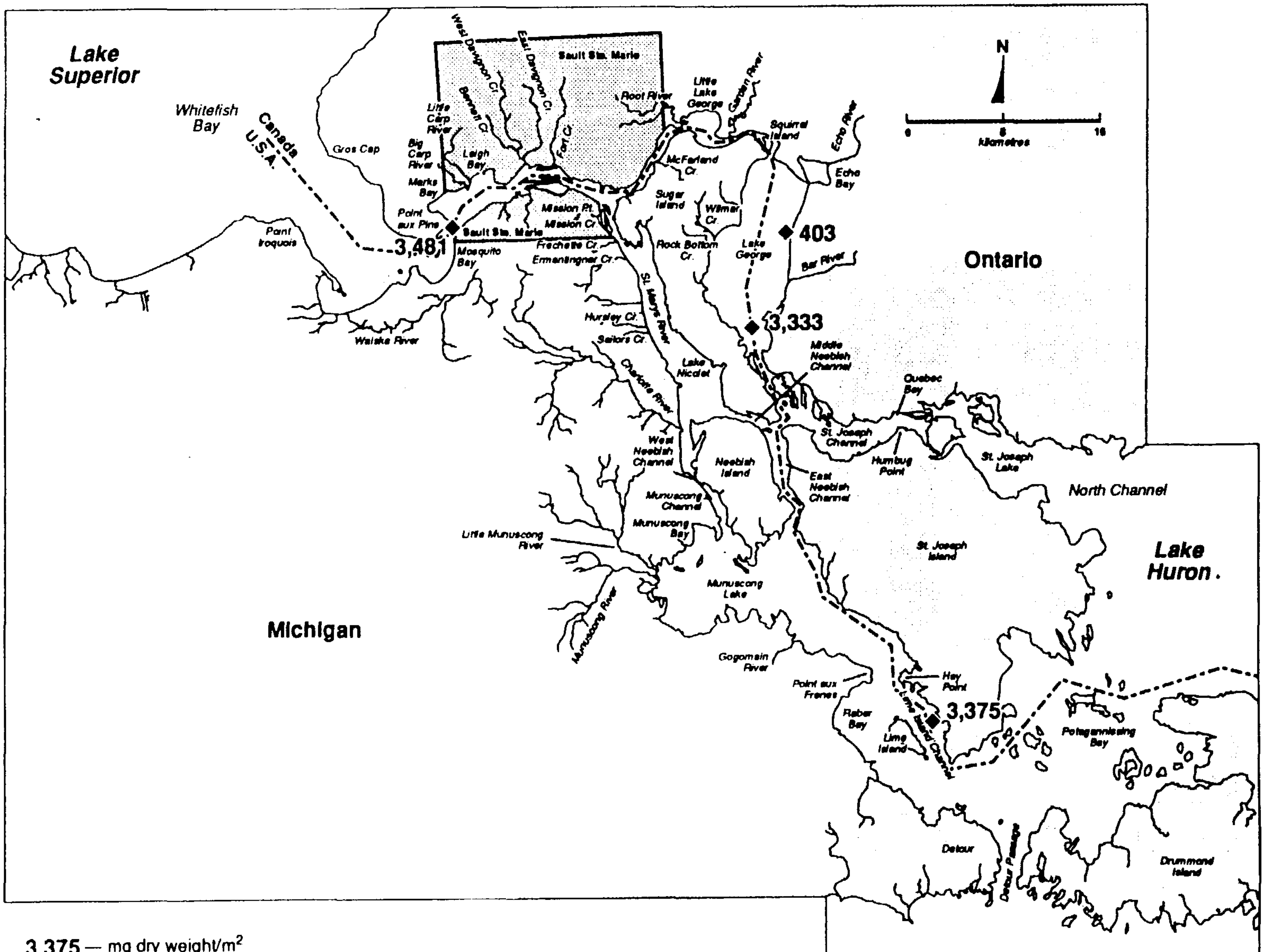
Information on contaminants in benthic invertebrates in the St. Marys River is limited; however, in 1983 OMOE determined the concentrations of arsenic and heavy metals in the numerically-abundant oligochaeta (*Tubifex tubifex* and *Limnodrilus hoffmeisteri*) and in sediments at four stations (Figure 6.49) located downstream of the Algoma Steel, St. Marys Paper, and East End WPCP discharges. On average, more than 75% of the cadmium, copper, lead and zinc, and more than 60% of the arsenic in the <63 µm diameter (silt and clay) fraction of sediments were in 'potentially available' forms. Based on the strength of the chemical extractants used, in decreasing order of biological availability (operationally defined), these include pore water > cation exchangeable > easily reducible > organic sulphides > moderately reducible (Fe/Mn oxides). However, most of the potentially available heavy metals were associated with the organic sulphide whereas most of the arsenic was in the easily reducible form. In contrast to the above elements, more than 75% of the iron and manganese was in the residual phase of sediments (not biologically available). At the four stations with sufficient oligochaetes for chemical analysis, concentrations of arsenic and metals in tissues were usually lower than in the St. Marys River sediment from which they were obtained (Table 6.20). The table also shows the bioconcentration factors (BCFs) for the various inorganic contaminants relative to their bulk sediment concentrations at the four sampling sites. The only location with a biological concentration factor of 1 or more for copper, zinc and mercury (Station 0045 near Little Lake George) had the lowest bulk sediment contaminant levels. It is noteworthy that the bioconcentration of these three metals was inversely proportional to the organic content of sediments, especially the solvent extractables (oil and grease) concentration. In sediments having high levels of organic carbon, biological uptake was very low, despite the fact that sediment metal concentrations were generally at their highest. Although BCFs are of concern with regard to the potential for biological magnification of contaminants through the aquatic food chain, the actual concentrations of contaminants within the oligochaetes are also important from the standpoint of the organisms' viability and behaviour. At present, there are no guidelines or criteria to compare the tissue concentrations in Table 6.20 with. However, comparison with the range for oligochaetes from all areas sampled in the Great Lakes in 1983 ('min.' to 'max.' in Table 6.20) indicates that, with the exception of arsenic, tissue concentrations in St. Marys River oligochaetes were closer to the lowest concentrations observed.

Figure 6.48

St. Marys River Remedial Action Plan

Production (mg dry weight/m²) of *Hexagenia limbata* nymphs in the St. Marys River, April to October 1986

(adapted from Edsall et al. in press)



3,375 — mg dry weight/m²

Hexagenia limbata nymphs production location

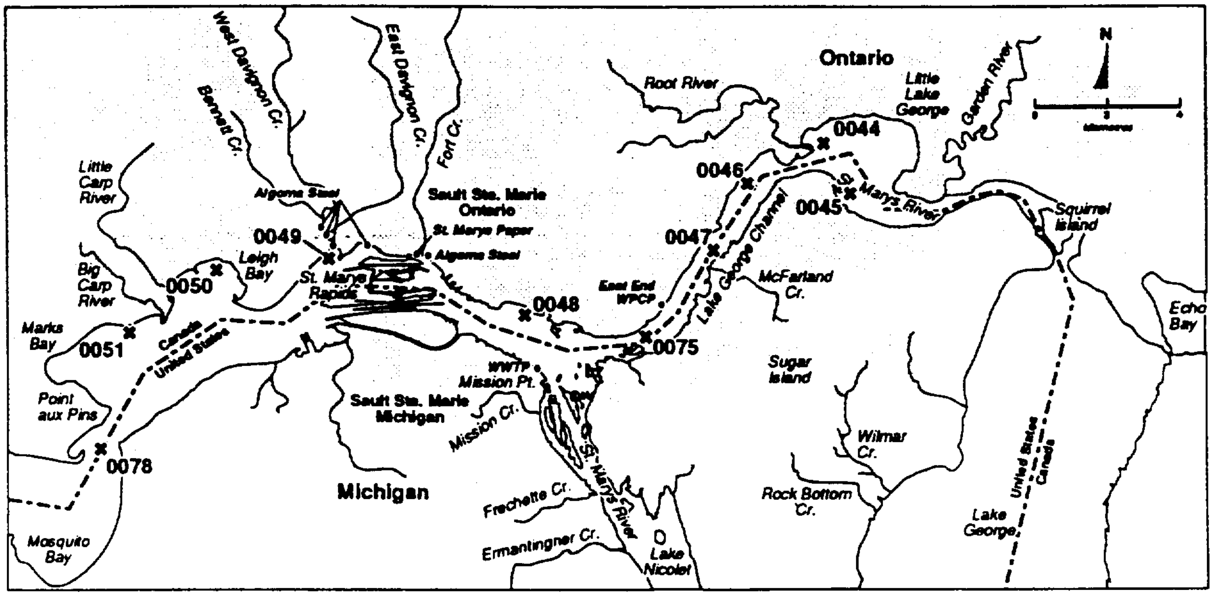
Figure 6.49

St. Marys River Remedial Action Plan

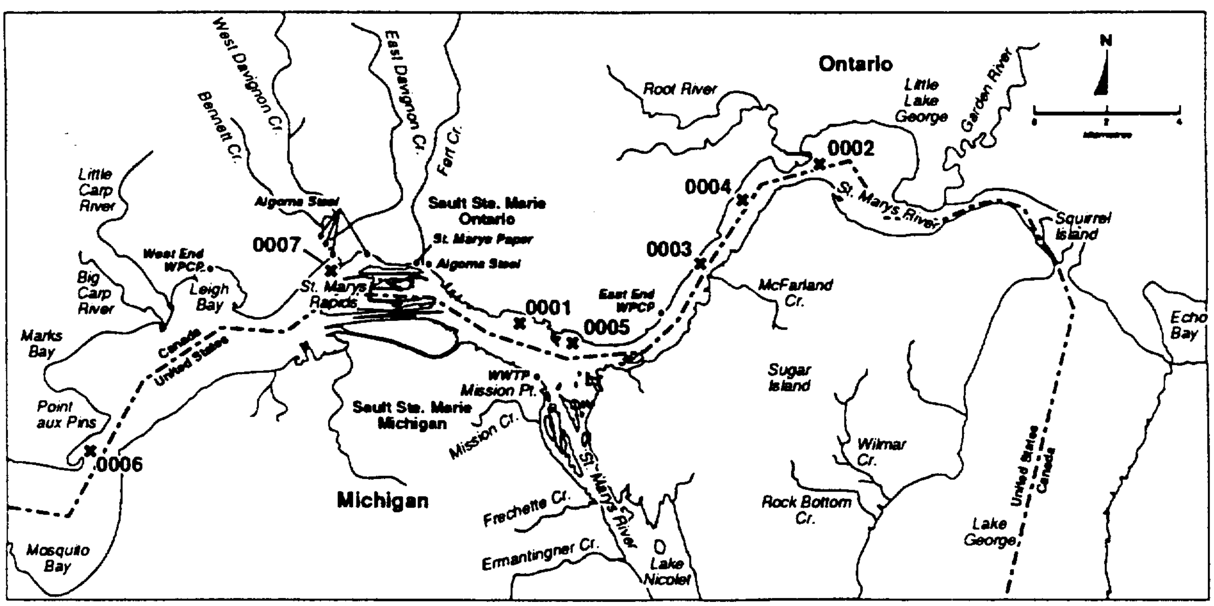
Sediment and oligochaete sampling stations in the St. Marys River in 1983 and in 1987

(Persaud et al. 1987 and Jaagumagi et al. 1991, respectively)

1983



1987



✖ sediment and oligochaete sampling station

• point source discharge location

Table 6.20 Concentrations of arsenic and metals in bulk sediments (mg/kg, dry weight) and benthic macroinvertebrates (oligochaeta) tissue (mg/kg, dry weight, gut-corrected) from different locations in the St. Marys River, 1983. (from Persaud *et al.*, 1987).

Station	Copper			Zinc			Lead			Cadmium		
	Sediment	Benthic Tissue	BCF	Sediment	Benthic Tissue	BCF	Sediment	Benthic Tissue	BCF	Sediment	Benthic Tissue	BCF
0045	23.1	22.5	1.0	118.7*	131.3	1.1	54.4*	2.4	0.0	1.0	0.3	0.3
0046	166.9*	24.1	0.1	730.3*	115.8	0.2	217.4*	0.2	0.0	3.5*	0.3	0.1
0047	89.4*	11.4	0.1	493.8*	107.5	0.2	157.1*	1.2	0.0	2.0*	0.3	0.2
0048	168.1*	17.0	0.1	947.3*	110.7	0.1	619.3*	6.8	0.0	4.5*	0.3	0.1
Min		9.6			62.9			0.0			0.1	
Max		82.0			663.4			60.6			1.2	

Station	Iron			Manganese			Mercury			Arsenic		
	Sediment	Benthic Tissue	BCF	Sediment	Benthic Tissue	BCF	Sediment	Benthic Tissue	BCF	Sediment	Benthic Tissue	BCF
0045	6,272.3	1,030.2	0.2	64.9	39.6	0.6	0.1	0.5	5.0	NA	NA	NA
0046	15,043.8	258.2	0.0	197.1	12.0	0.1	0.6	0.3	0.5	34.3	18.0	0.5
0047	8,949.2	715.1	0.1	128.0	8.5	0.1	0.4	0.1	0.3	NA	NA	NA
0048	13,280.3	104.2	0.0	362.4	-1.2†	0.0	0.6	0.0	0.0	NA	NA	NA
Min		104.2			1.2			0.0			0.7	
Max		41,665.7			183.7			0.6			21.6	

Note: Station locations shown in Figure 6.49.
* Exceeds Ontario Ministry of the Environment guideline for the open water disposal of dredged materials.
† Negative value is the result of extremely low levels of manganese in benthic tissues compared with the sediment concentration.
BCF - Biological concentration factor.
NA - Not available.
Min and Max - Minimum and maximum concentrations detected in oligochaetes from all areas sampled in 1983 (from Persaud *et al.*, 1987).

Further studies were conducted in 1985 and 1987 (Figure 6.49) as part of the OMOE's MISA initiative in the St. Marys River (in the vicinity of Algoma Steel and the East End WPCP) to determine the environmental impacts of both metal and organic contaminants in sediments on resident biota, including benthic invertebrates and fish (Jaagumagi *et al.*, 1991). This ecosystem approach was designed to determine whether either the Algoma Steel mill or the East End WPCP were a major source of contaminants to biota in the AoC.

As in 1983, Jaagumagi *et al.*, 1991 found that the accumulation of metals by benthic invertebrates in 1987 could not be directly related to bulk sediment metal levels. Tissue metal levels fluctuated only slightly, despite large fluctuations in sediment levels. Arsenic and mercury were the only metals that bioaccumulated in tissues to levels higher than in sediments (Figure 6.50). Also, levels of metals in invertebrate tissues could not be directly related to their concentrations in any particular sediment fraction.

With the exception of PAHs, organic contaminant levels were low in sediments, and only PCBs were found in organisms from some stations at levels higher than in sediments (Figure 6.50).

The authors found that any contaminant effects on the biota that may have been due to the East End WPCP could not be differentiated from upstream sources. Similarly, an effect from the St. Marys Paper Co. mill, if present, could not be separated from the effects of the Algoma Steel mill, except in terms of increased levels of chlorophenols uptake in laboratory bioassays. Furthermore, sediments from these stations were not acutely toxic to either *Hexagenia limbata* nymphs or fathead minnows during the 10-day laboratory bioassays (Table 6.21).

Table 6.21 Acute toxicity laboratory bioassay results for sediments collected from the St. Marys River in 1987 (Jaagumagi *et al.*, 1991).

Station	Percent Mortality Over 10 Days	
	Fathead Minnows	Mayfly (Hexagenia) Larvae
0006	0	13.3
0007	0	6.7
0001	0	6.7
0005	0	13.3
0003	0	6.7
0004	0	20
0002	0	20
Control	0	0

Notes: 1). Refer to figure 6.49 for station location.
2). The above percentages are the average of three replicates.

Jaagumagi *et al.* (1991) concluded that their sampling program was limited in its ability to demonstrate direct cause-effect relationships between sediment contamination and bottom faunal effects. In fact, they argued that impacts could only be inferred because suitable mechanistic explanations were lacking for contaminant movement in sediments as well as impacts on biological systems. Nevertheless, the speculated effects of contaminant loads (point source discharges as well as spills) on benthic community structure, as well as absolute levels of specific pollutants in individual organisms, strongly argued for further controls on sources of pollution.

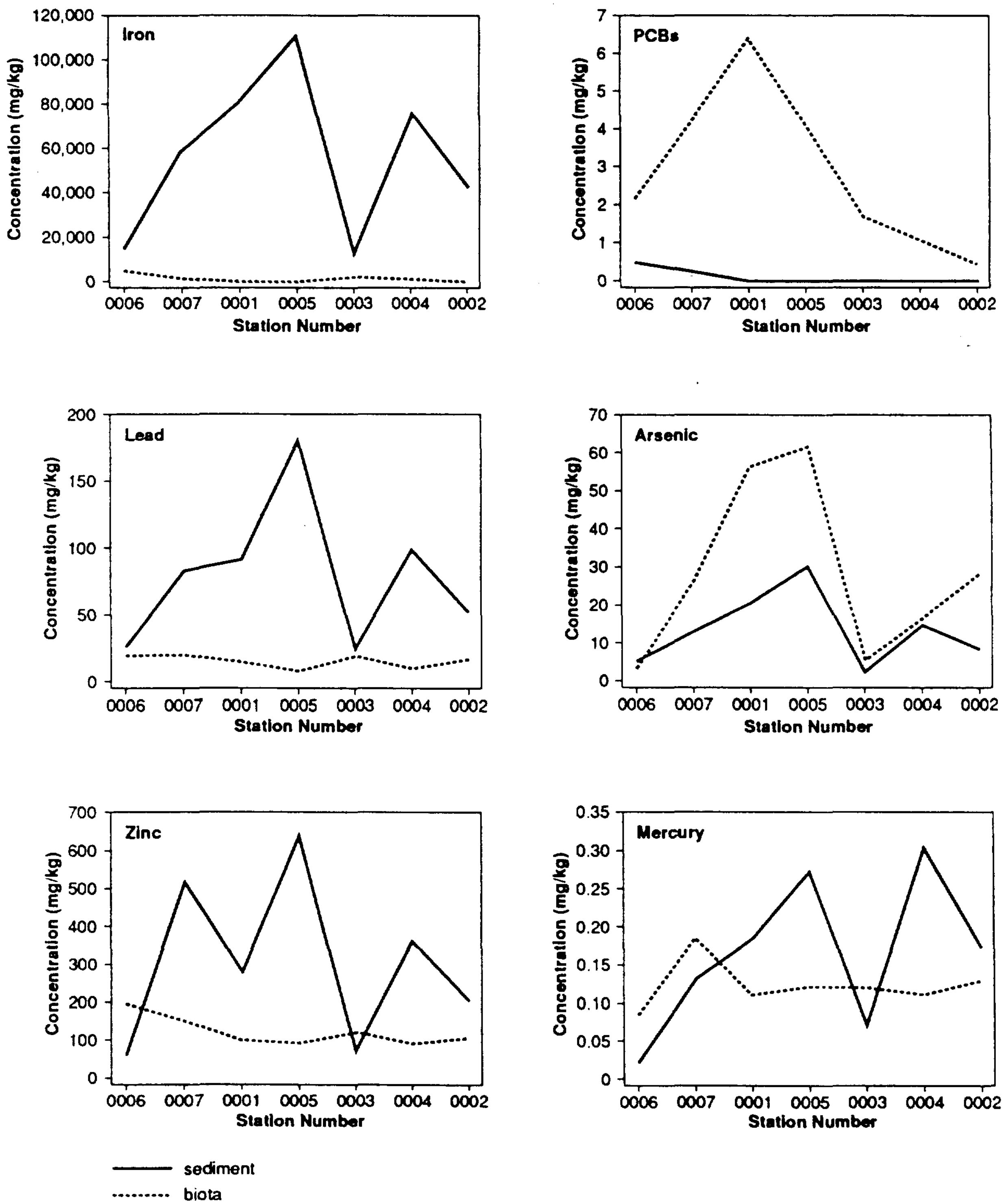
Figure 6.50

St. Marys River Remedial Action Plan

Relationship of contaminant concentrations in benthic macroinvertebrate tissue (wet weight corrected for dry weight and gut contents) to those in bulk sediment (dry weight) samples from the St. Marys River, 1987

All organisms were oligochaetes, except for station 0006, which were Hexagenia nymphs; see Figure 6.49 for station locations

(adapted from Jaagumagi et al. 1991)



In general, the above studies suggest that polluted sediments can be a source of contaminants to organisms, particularly if the organic carbon content of the sediment is low. As discussed earlier (Section 6.6.4) contaminants from point source discharges and spills can completely eliminate benthic populations, or reduce the diversity to a few tolerant species such as *Tubifex tubifex* and *Limnodrilus hoffmeisteri*. Even then, the concentrations of certain metals in the tissues of these surviving organisms implies concerns of potential contaminant transfer to higher trophic levels.

6.6.6.2 Mussels

In 1984, uncontaminated caged unionid mussels were exposed in nearshore waters of the St. Marys River for a three week period. As described by Kauss and Hamdy (1991), mussels placed in areas near and downstream from the Ontario discharges accumulated significantly higher levels of PAHs such as phenanthrene (one of the most abundant PAHs in mussels) than those exposed at upstream locations (Figure 6.51). Accumulations along the Michigan shoreline were generally at lower levels than along the Ontario shore. In 1985, mussels exposed in the Algoma Steel Slip accumulated the highest levels of total PAHs (Figure 6.51). Nevertheless, concentrations of benzo(a)pyrene (maxium value 0.013 mg/kg), a known carcinogen (Table 6.4), in mussels was well below the proposed IJC objective of 1 mg/kg for organisms serving as a food source for fish (Kauss 1991).

6.6.7 Summary

The St. Marys River benthic community is diverse, with 303 taxa on record. Its composition is influenced mainly by: substrate type character, water depth and temperature, currents and wave action, the presence and density of aquatic vegetation and in certain areas, industrial and municipal pollution. Statistical analyses of stations sampled in 1985 revealed that industrial and municipal discharges severely impacted the benthic macroinvertebrate communities in the Algoma Slip and in downstream embayments along the Ontario shoreline. Moderate impairment was generally restricted to a narrow band approximately 500 m wide, extending 4 km along the Ontario shore downstream of industrial discharges. Some recovery was apparent about 5 km downstream from the Algoma Steel and St. Marys Paper discharges however, complete recovery did not occur until the lower section of Lake George, some 24 km downstream from these discharges. Clean water (unimpaired) fauna characterized the non-industrialized Michigan shore, the entire river upstream of pollutant sources, and Lake Nicolet.

Statistical analysis to determine correlations between sediment quality and benthic communities (community index analysis) revealed similar zones of impact as shown by the cluster evaluation approach. Discriminant analysis identified a heavy metal-particle size gradient and a pesticide-particle size gradient in sediment quality, which together provides a basis for separating impacted station clusters from each other and from unimpaired stations.

Despite considerable reductions in various contaminant concentrations in the river including phenol, ammonia, oil and grease, cyanide, etc., substantial improvements have not been observed in the AoC's impaired benthic communities. Sediments continuing to have visible oily residues are characterized by low numbers or the complete absence of the burrowing mayfly *Hexagenia limbata*. Production of nymphs of *Hexagenia limbata* is also markedly depressed by the presence of high concentrations of oil, cyanide and heavy metals.

Contaminants from point source discharges, spills and bottom sediments are generally considered to affect benthic organisms, either by completely eliminating communities or by reducing their diversity or productivity. Metal concentrations in sediment-dwelling organisms (tubificids) generally correlate poorly with concentrations sediment. Arsenic and mercury are the only metals that appear to be bioaccumulating in benthic organisms. Organic contaminant bioaccumulation was generally low, with only some of the more persistent organics (PCBs) accumulating in organic tissues of benthic organisms.

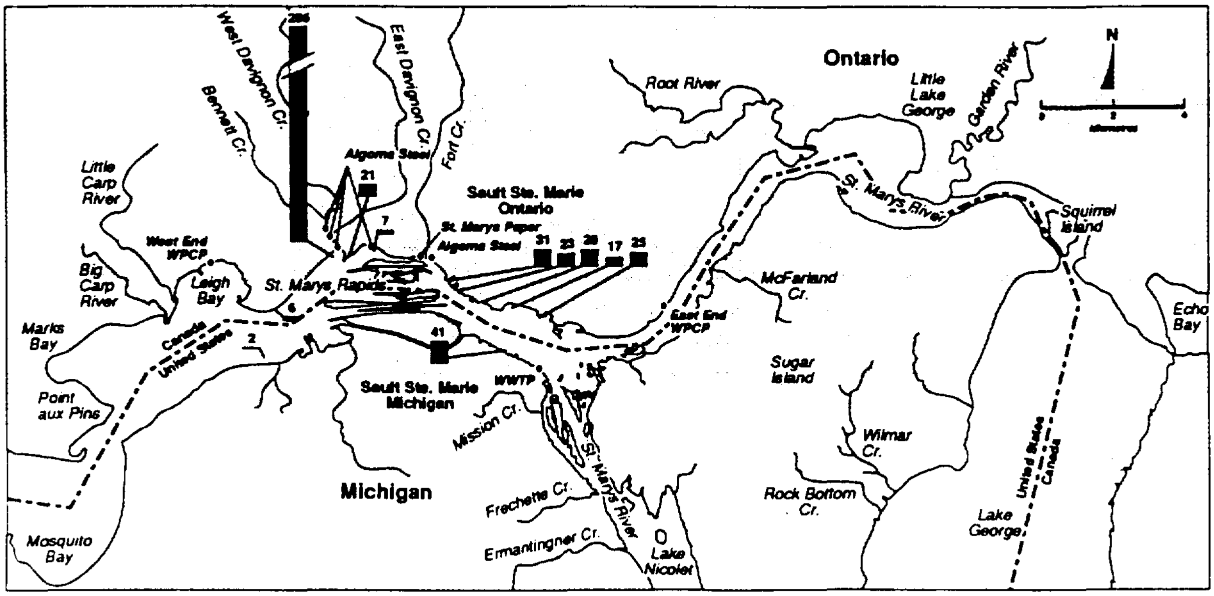
Figure 6.51

St. Marys River Remedial Action Plan

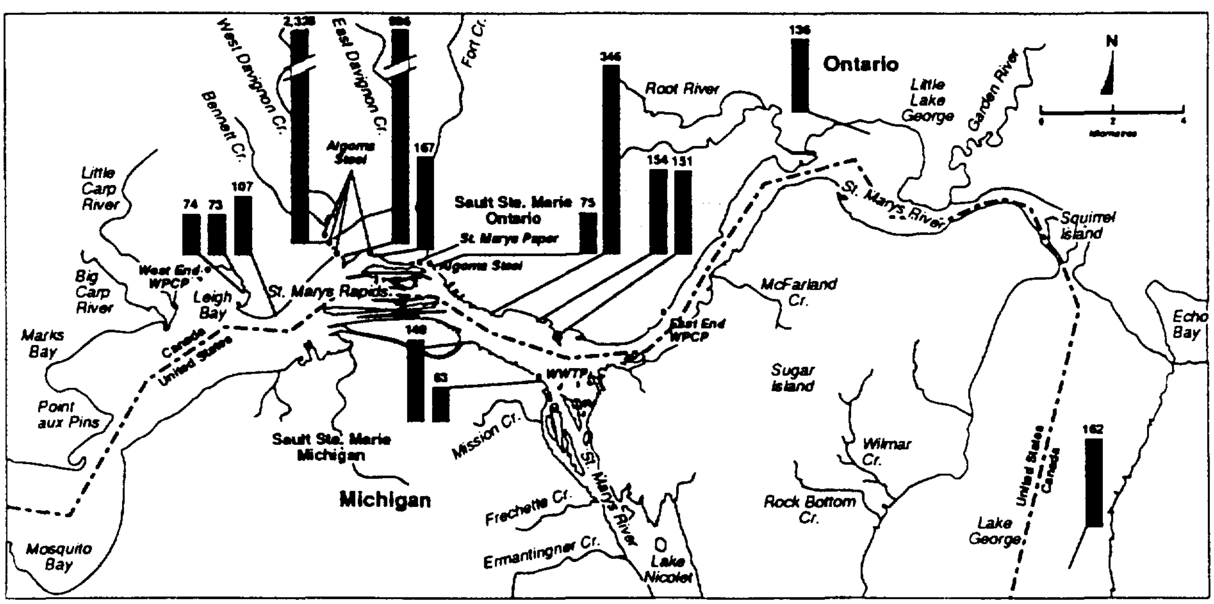
Concentration (µg/kg, wet weight) of phenanthrene in 1984 and of total PAHs in 1985 in caged mussels (*Elliptio complanata*) after three weeks' exposure in the St. Marys River

(from Kauss and Hamdy 1991)

1984



1985



• point source discharge location

■ concentration (ng/g or ppb)

Uncontaminated mussels exposed to river water near and downstream of Ontario discharges accumulated significantly higher levels of certain PAH compounds than mussels introduced in the river upstream from the discharges. Accumulations along the Michigan shoreline were generally at lower levels than along the Ontario shore. Mussels exposed in the Algoma Steel Slip contained the highest levels of total PAHs. However, concentrations of benzo(a)pyrene were well below the proposed IJC objective of 1 mg/kg for organisms serving as a food source for fish.

6.7 FISH, AMPHIBIANS AND REPTILES

6.7.1 Fish

6.7.1.1 Composition and Distribution

The fish community of the St. Marys River is a complex mixture 74 species of warm, cool and coldwater fish (Appendix 6.8), although many are considered to be transient or rare. This high number results from the diversity of fish habitats within the river, as well the rivers connections to the fish communities of Lakes Superior and Huron. Ryder and Kerr (1978) described the current community as foremost a warmwater percid one which is characterized by the presence of *Stizostedion vitreum* (walleye), *Esox lucius* (northern pike), *Perca flavescens* (yellow perch) and *Catostomus commersoni* (white sucker). Twelve species which occur in the river have been either intentionally or accidentally introduced into the Great Lakes basin, or have gradually invaded from the Atlantic Ocean (Table 6.22). *Osmerus mordax* (rainbow smelt) is now an important forage fish in the AoC (U.S.ACOE, 1988) and salmon, *Oncorhynchus mykiss* (rainbow trout) and *Salmo trutta* (brown trout) are important sport fish.

Table 6.22 Exotic fish introductions to Lake Superior with year of introduction or first record in parentheses (Lawrie, 1978).

"Planned" Introductions	"Accidental" Introductions
Rainbow Trout (1895)	Carp (1915)
Brown Trout (ca. 1900)	Rainbow Smelt (1930)
Coho Salmon (1966)	Sea Lamprey (1946)
Chinook Salmon (1967)	Alewife (1954)
Atlantic Salmon (1972)	Pink Salmon (1956)
	Gizzard shad*
	Goldfish*

* Occurrences are rare. Year of introduction is not known.

Adult spawning sea lamprey (*Petromyzon marinus*) are abundant in the St. Marys Rapids, and below the Clerque Generating Station from about June 15 to August 15. The larvae are found from Whitefish Bay to Munuscong Lake. Population estimates for adult sea lamprey in the St. Marys River showed a decline from 10,964 in 1976 to 3,136 in 1978, however they have since increased from approximately 17,000 in 1985 to almost 27,000 in 1989 at the Clerque Generating Station and the USACOE Power Plant (DFO/U.S.FWS, Sea Lamprey Control Office, Data Files) (see section 5.5.5.2). Because adult sea lamprey feed in the lakes, there is less damage to fish in the St. Marys River. However, there is increasing concern that the large lamprey population in the river is contributing to the increased mortality of fish, particularly salmon and lake trout (*Salvelinus namaycush*) mostly in Lake Huron. For example, migratory species such as salmon show a high incidence of wounds (40-60 wounds per 100 fish, 1986-1990) when they return to the river

(DFO/U.S.FWS, Sea Lamprey Control Office, Data Files). The large size of the St. Marys River complicates chemical treatment of lamprey larvae; however the Lake Huron Technical Committee recognizes this and has set an objective of a 75% reduction in the abundance of spawning adults by the year 2000 and a 90% reduction by 2010 (DFO/U.S.FWS, Sea Lamprey Control Office, Files) (see section 5.5.5.2).

Fish species of the AoC are normally associated with one of four primary habitats: open water and embayments, emergent wetlands, sand and gravel beaches and the St. Marys Rapids. However, many can also be found in more than one habitat, either as they mature from larvae to adults, or as a result of diel or seasonal migration.

Fish species using a particular section of the river may change considerably throughout the year, as migratory species inhabit an area during spawning, and then leave the immediate area, perhaps even the river. For example, pink salmon are very abundant in the river during the late summer and fall of odd-numbered years and migrate to the rapids and most tributaries for spawning. Chinook salmon and coho salmon exhibit false runs in the spring, but migrate upstream in late summer and fall to spawn (Krishka 1989). Rainbow trout and rainbow smelt are other migratory species which use St. Marys River tributaries and rapids for spawning in spring. These species are believed to leave the river following spawning however, both have been observed in the rapids during other times of the year (Hamilton 1987). Smelt are regularly fished with dip nets below the Clerque Generating Station in July. Walleye exhibit a pre-spawning migration toward Munuscong Lake from most areas of the St. Marys River (Figure 6.52) however, unlike the migratory salmonoids, they tend to remain within the river system following post-spawning dispersion, and reappear in the rapids during late summer, presumably to feed. Krishka (1989) has idendified the Rapids as critical habitat for walleye. However, it is uncertain whether walleye spawn or simply use the Rapids for forage. Sexually mature atlantic salmon return to the river from May to July (S. Scott, MDNR, pers. comm.). Fish production in the Lake Nicolet reach of the river is about 1.2 g AFDW/m^2/yr or 29 tonnes AFDW/year (Edwards *et al.*, 1989). The latter is 0.5% and 6.3% of the annual primary and secondary production respectively, in Lake Nicolet (Kauss 1991).

The St. Marys Rapids has been subject to dewatering, with attendant adverse impacts on fish habitat, fish fry and benthic macroinvertebrates (Kauss 1991). It is suspected that dewatering results in a reduced spawning area and food source (i.e. the reduction of macroinvertebrate populations) and hence a reduction in fish populations (P. Kauss, OMOE, pers. comm.). Intermittent dewatering may result in the destruction of a variety of fish fry inhabiting the rapids. In 1985 a berm was constructed in order to maintain water levels along the Ontario side of the Rapids during periods of reduced flow.

Although the fish populations appear to be healthy, concerns are now being raised by the public suggesting that native fish populations, such as lake whitefish and lake herring, are declining. Stocking efforts are concentrating mainly on the introduced species, such as salmon and rainbow and brown trout, for sport fishing and tribal commercial and subsistence fishing are reducing the native species. Quantitative data supporting this concern is not available and it is not known what impact the exotic species have on native species or habitat.

In summary, a complex fish community exists in the river, providing dynamic, year around sport fishing. An important tribal fishery exists for whitefish and lake trout in the upper river and Lake Superior, and subsistence fishing is carried out by native peoples throughout the St. Marys River (see Sections 5.5.5, 6 & 7). Human interference has changed the ecosystem and fish habitat of the St. Marys River, particularly in the Rapids. Humans have also been instrumental in changing the dominant fish species composition throughout the Great Lakes by the introduction of exotic species such as salmon, rainbow and brown trout. The increasing population of adult spawning sea lamprey in the St. Marys River suggests that sea lamprey are contributing to the increased mortality of fish, particularly salmon and lake trout in Lakes Huron and Superior.

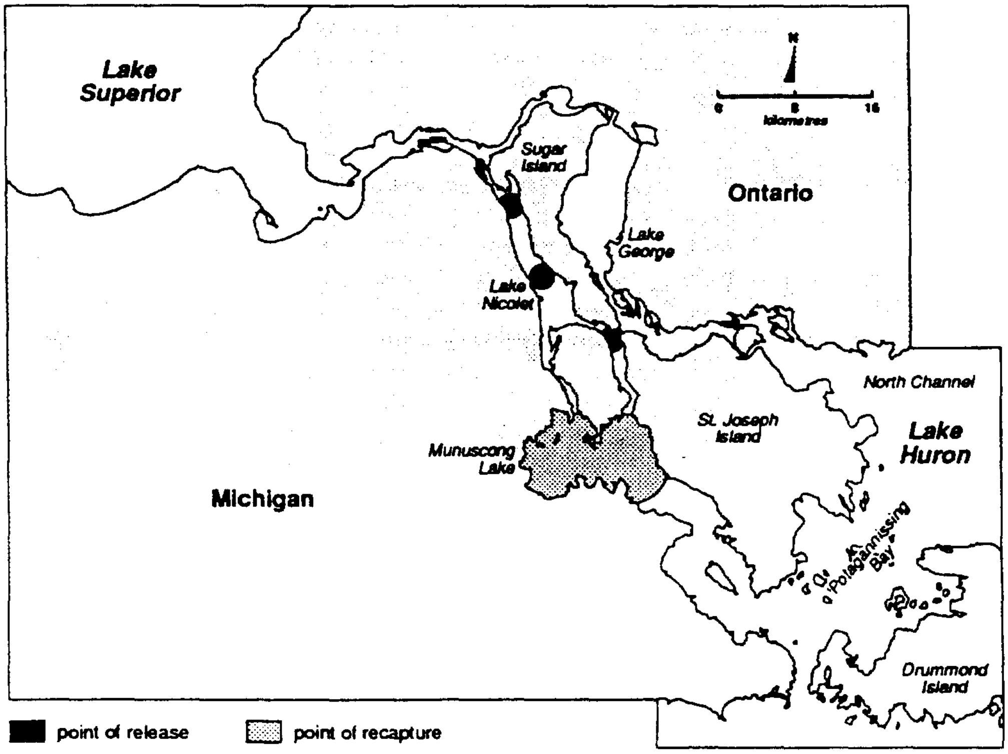
Figure 6.52

St. Marys River Remedial Action Plan

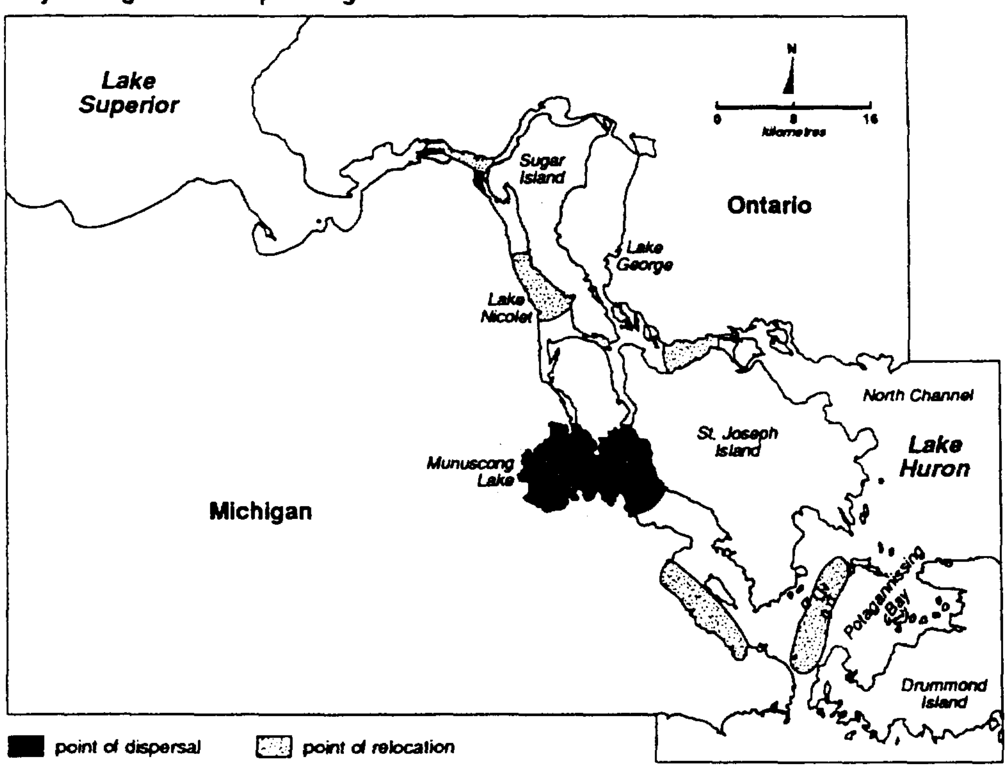
Migration of walleye in the St. Marys River towards Munuscong Lake during January to February and dispersal from the lake in July to August

(from Duffy et al. 1987)

January to February: Pre-spawning movement



July to August: Post-spawning movement



6.7.1.2 Contaminants in Fish

To date, major impacts from industrial and municipal sources of pollution, such as those observed for benthic macroinvertebrates, have not been demonstrated for fish (Edsall *et al.*, 1988). Analyses of young-of-the-year yellow perch and spottail shiners collected in 1979, 1983 and 1987 from Ontario waters at Sault Ste. Marie and in Little Lake George indicated that concentrations of organochlorine contaminants (in whole fish), when detected, were low. For example, total PCBs averaged 0.025 mg/kg or less, and were below the GLWQA objective of 0.100 mg/kg for the protection of birds and animals which consume fish. Other chlorinated organics were at low or non-detectable levels in the perch and shiners tested (Table 6.23). Spottail shiners obtained from Little Lake George in 1987 were also analyzed for PAHs. Only naphthalene was detected in the fish, at an average concentration of 0.023 mg/kg (Table 6.23).

Table 6.23 Organic contaminants in juvenile fish from Ontario waters of the St. Marys River in 1979, 1983 and 1987 (adapted from Suns et al. 1985 and 1991).

Contaminant	Mean concentration (mg/kg, wet weight)				
	Agreement Objective*	1979 Little Lake George	1983 Sault Ste. Marie	1983 Little Lake George	1987 Little Lake George
PCB (total)	0.100	trace (<0.20)	0.025	trace (<0.020)	ND
Chlordane (α, γ)	NA	0.003	ND	0.003	ND
BHC (α, β, γ)	NA	0.005	ND	0.005	ND
DDT and Metabolites	1.0	0.005	0.010	0.005	ND
Mirex	<detection	ND	ND	ND	ND
Chlorinated benzenes (tri-, tetra-, penta-, hexa-; trichlorotoluene, octachlorostyrene)	NA	NA	ND	NA	ND
Chlorinated aliphatics (hexachloroethane, hexachlorobutadiene)	NA	NA	ND	NA	NA
Chlorinated phenols (tri-, tetra-, penta-)	NA	NA	ND	NA	NA
Polycyclic aromatic hydrocarbons	NA	NA	NA	NA	0.023

Notes: Data are mean concentrations for young-of-the-year yellow perch and spottail shiners from Sault Ste. Marie, Ontario and Little Lake George
*Specific objectives for the projection of birds and animals which consume fish (IJC, 1987).
NA - Not available
ND - Not detected

Data on organochlorine contaminants in adult fish (Table 6.24) indicate that total PCB concentrations in St. Marys and Tahquamenon Rivers fish were estimated to exceed GLWQA objectives for the protection of fish eating birds and animals (Kauss 1991). However, estimates of contaminant concentrations in St. Marys River fish were "semi-quantitative" (Jaffe *et al.* 1985) and conclusions about exceedences of GLWQA objectives are speculative. Kauss (1991) noted that there was a lack of objectives for the majority of contaminants detected in the fish, thereby making judgement of their importance to higher levels of the food chain difficult.

Since 1976, sport fish collected by OMNR in Ontario waters of the St. Marys River have been analyzed by OMOE for mercury, PCBs and organochlorine pesticides such as DDT and mirex. In 1980, walleye from the St. Joseph Island area were also analyzed for 2,3,7,8-tetrachlorodibenzo-p-dioxin. This compound was not detected in any of the fish samples. For the most recent collections in 1987 and 1989, dorsal fillets of some species were also analyzed for polycyclic aromatic hydrocarbons (PAHs), chlorinated aliphatics and benzenes

Table 6.24 Contaminants in whole adult fish from the St. Marys River neighbouring Lakes Superior and Huron. (Kauss 1991).

Contaminant	Concentration (mg/kg, wet wt.)			
	Agreement Objective*	L. Superior	St. Marys R.	L. Huron
		a	a	b
PCB (total)	0.100	0.009	0.146-1.488	>1.000
BHC (α)	NA	ND	ND-0.001	ND-0.019
Chlordane(α, γ)	NA	0.0001	0.001-0.005	0.009-0.110
Nonachlors	NA	0.0004	0.003-0.008	0.012-0.120
Dieldrin	NA	0.0002	0.002-0.003	ND-0.010
DDT and metabolites	1.000	0.002	0.010-0.143	0.145-0.730
Heptachlor epoxide	NA	ND	ND	ND
Mirex	<detection	NA	NA	ND-0.069
Dichlorobenzene	NA	NA	NA	0.610-1.800
1,2,3,4-Tetra-chlorobenzene	NA	NA	ND	NA
1,2,4,5-Tetra-chlorobenzene	NA	ND	ND	NA
Pentachlorobenzene	NA	ND	ND-0.001	NA
Hexachlorobenzene	NA	ND-0.0001	0.0006-0.001	ND-0.017
Octachlorostyrene	NA	ND	ND-0.017	ND-0.006
PAH (total)	NA	NA	NA	0.045-0.119

Sources: a Jaffe *et al.* (1985), semi-quantitative 1983 data for white sucker and carp from Michigan waters of the St. Marys River and for white sucker from the Tahquamenon River, Whitefish Bay;
b Zenon (1985), 1983 data for white sucker and brown bullhead from Ontario waters of the North Channel, Lake Huron.

Notes: * specific objectives for the protection of birds and animals which consume fish (IJC, 1978)
NA not available
ND not detected

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and chlorinated phenols; certain 1987 fish were also analyzed for nine additional elements, including arsenic. These recent data are summarized in Table 6.25 and presented in greater detail (i.e., by species, mean concentration) in Appendix 6.9.

Since there were no "control" sites sampled in the upper St. Marys River, compairisons of contaminant levels in sport fish from immediately above and below Sault Ste. Marie cannot be made. However, data for fish from Batchawana Bay in Lake Superior and from Algoma Mills in the North Channel of Lake Huron are included in Table 6.25 to provide upstream and downstream references for the St. Marys River sites. 1986, 1987 and 1989 MDNR collections from Michigan waters are also included for comparison. It should also be noted that data on the same fish species is not available for all areas, thereby making comparisons between different areas difficult. For example, walleye are highly mobile within the St. Marys River, and salmon are

Table 6.25 Contaminants in dorsal fillets of adult sport fish from Ontario and Michigan waters of the St. Marys River. Prepared from 1987 and 1989 OMNR/OMOE data from the Sport Fishing Program (Appendix 6.9) and the MDNR Fish Contaminant Monitoring Program, 1986 (Munuscong Lake), 1987 (Sugar Island) and 1989 (Drummond Island) (Appendix 6.9) (OMOE unpublished data, Duling and Benzie 1989 and 1990).

Contaminant	Concentration mg/kg (net weight)										
				Lake Superior	St. Marys River Ontario			St. Marys River Michigan			North Channel
	Fish Cons'n Guidel.*	MDPH trig. level†	MRL	Batchahawana Bay Range	below Rapids Range	Lake George Range	St. Joseph Is. Area Range	Sugar Island Range	Munuscong Lake Range	N. Drummond Is. Range	Algoma Mills Range
Metals and PCBs											
Arsenic	-	-	-	-	0.01-0.04	-	-	-	-	-	-
Cadmium	-	-	0.040	-	<0.040-0.096	-	-	-	ND	-	-
Chromium	-	-	-	-	ND-0.40	-	-	-	ND	-	-
Copper	-	-	-	-	0.50-1.00	-	-	-	ND	-	-
Lead	1.0	-	-	-	ND	-	-	-	ND	-	-
Manganese	-	-	-	-	ND-0.20	-	-	-	-	-	-
Mercury	0.50	0.50	0.01	-	<0.01-1.17	0.08-0.69	0.13-0.38	0.135-0.320	0.140-1.000	0.150-0.330	0.03-0.38
Nickel	-	-	-	-	ND-0.70	-	-	-	ND	-	-
Selenium	-	-	-	-	0.80-1.30	-	-	-	-	-	-
Zinc	-	-	-	-	3.00-8.20	-	-	-	3.600-7.400	-	-
PCBs (total)	2.0	2.0	0.020	ND-0.120	ND-2.940	ND-0.170	ND-0.050	ND-0.092	0.035-0.379	ND-0.088	0.040-1.960
Pesticides and Herbicides											
Aldrin	0.3‡	-	0.001	ND	ND	ND	ND	ND	-	ND	ND
α-BHC	-	-	0.001	ND-0.003	ND-0.008	ND-0.004	ND	-	-	-	ND-0.004
-BHC	-	-	0.001	ND	ND	ND	ND	ND	-	-	ND
γ-BHC (Lindane)	0.3	-	0.001	ND	ND-0.001	ND	ND	ND	-	ND	ND
α-Chlordane	-	0.3	0.002	ND-0.008	ND-0.061	ND-0.001	ND-0.001	ND-0.005	-	ND	ND-0.025
γ-Chlordane	-	0.3	0.002	ND	ND-0.028	ND	ND-0.001	ND	-	ND	ND-0.012
Dieldrin	-	-	-	-	-	-	-	ND	-	ND	-
o,p-DDT	5.0‡	5.0	0.002	ND	ND-0.008	ND	ND	-	-	-	ND-0.006
p,p'-DDT	‡	-	0.002	ND-0.013	ND-0.084	ND-0.006	ND-0.002	ND-0.013	-	ND	ND-0.099
p,p'-DDD	‡	-	0.002	ND	ND-0.040	ND-0.002	ND	ND	-	ND	ND-0.030
p,p'-DDE	‡	-	0.001	0.002-0.036	ND-0.557	ND-0.025	ND-0.009	ND-0.440	-	0.003-0.034	0.006-0.642
Heptachlor	0.3	0.3	0.001	ND	ND	ND	ND	ND	-	ND	ND
Heptaclor-Epoxide	-	-	-	-	-	-	-	ND	-	ND	-
Mirex	0.1	0.1	0.005	ND	ND	ND	ND	ND	-	ND	ND-0.011

Table 6.25 (Cont'd)

Contaminant	Fish Cons'n Guidel.*	MDPH trig. level†	MRL	Lake Superior: Batchahawana Bay Range	St. Marys River Ontario: below Rapids Range	St. Marys River Ontario: Lake George Range	St. Marys River Ontario: St. Joseph Is. Area Range	St. Marys River Michigan: Sugar Island Range	St. Marys River Michigan: Munuscong Lake Range	St. Marys River Michigan: N. Drummond Is. Range	North Channel: Algoma Mills Range
cis-Nonachlor	-	-	-	-	-	-	-	ND-0.005	-	ND	-
trans-Nonachlor	-	-	-	-	-	-	-	ND-0.013	-	ND	-
Oxy-chlordane	-	-	-	-	-	-	-	ND	-	ND	-
Toxaphene	3.0	-	0.100	ND	ND-1.570	ND-0.130	ND	ND	-	ND	ND-0.710
Chlorinated Organics											
Hexachloroethane	-	-	0.001	ND	ND	ND	ND	-	-	-	ND
Hexachlorobutadiene	-	-	0.001	ND	ND	ND	ND	-	-	-	ND
1,2,3-Trichlorobenzene	-	-	0.002	ND	ND	ND	ND	-	-	-	ND
1,2,4-Trichlorobenzene	-	-	0.002	ND	ND	ND	ND	-	-	-	ND
1,3,5-Trichlorobenzene	-	-	0.002	ND	ND	ND	ND	-	-	-	ND
2,3,6-Trichlorotoluene	-	-	0.001	ND	ND	ND	ND	-	-	-	ND
2,4,5-Trichlorotoluene	-	-	0.001	ND	ND	ND	ND	-	-	-	ND
1,2,3,4-Tetrachlorobenzene	-	-	0.001	ND	ND	ND	ND	-	-	-	ND
1,2,4,5-Tetrachlorobenzene	-	-	0.001	ND	ND	ND	ND	-	-	-	ND
Hexachlorobenzene	-	-	0.001	ND-0.002	ND-0.012	ND-0.001	ND	ND	-	ND	ND-0.003
Hexachlorostyrene	-	-	-	-	-	-	-	ND	-	ND	-
Heptachlorostyrene	-	-	-	-	-	-	-	ND	-	ND	-
Octachlorostyrene	-	-	0.001	ND	ND	ND	ND	ND	-	ND	ND-0.004
Pentachlorobenzene	-	-	0.001	ND	ND	ND	ND	-	-	-	ND
Pentachlorostyrene	-	-	-	-	-	-	-	ND	-	ND	-
Phenols											
2,3,4-Trichlorophenol	-	-	0.100	ND	ND	ND	ND	-	-	-	ND
2,4,5-Trichlorophenol	-	-	0.050	ND	ND	ND	ND	-	-	-	ND
2,4,6-Trichlorophenol	-	-	0.050	ND	ND	ND	ND	-	-	-	ND
2,3,4,5-Trichlorophenol	-	-	0.050	ND	ND	ND	ND	-	-	-	ND
2,3,5,6-Trichlorophenol	-	-	0.050	ND	ND	ND	ND	-	-	-	ND
2,3,4,5-Tetrachlorophenol	-	-	0.050	ND	ND	ND	ND	-	-	-	ND
2,3,5,6-Tetrachlorophenol	-	-	0.050	ND	ND	ND	ND	-	-	-	ND
Pentachlorophenol	-	-	0.050	ND	ND	ND	ND	-	-	-	ND
Polybrominatedbiphenyl	-	-	-	-	-	-	-	ND	-	ND	-
Terphenyl	-	-	-	-	-	-	-	ND	-	ND	-

Table 6.25 (Cont'd)

Contaminant	Concentration mg/kg (net weight)										
	Fish Cons'n Guidel.*	MDPH trig. level'	MRL	Lake Superior	St. Marys River Ontario			St. Marys River Michigan			North Channel
				Batchahawana Bay Range	below Rapids Range	Lake George Range	St. Joseph Is. Area Range	Sugar Island Range	Munuscong Lake Range	N. Drummond Is. Range	Algoma Mills Range
PAHs											
Acenaphthene	-	-	0.008	ND	ND-0.022	ND-0.022	ND	-	-	-	ND
Acenaphthylene	-	-	0.005	ND	ND-0.024	ND	ND	-	-	-	ND
Anthracene	-	-	0.009	ND	ND	ND	ND	-	-	-	ND
Benzo[a]anthracene	-	-	0.005	ND	ND-0.010	ND-0.010	ND	-	-	-	ND
Benzo[b]fluoranthene	-	-	0.007	ND	ND-0.007	ND-0.007	ND	-	-	-	ND
Benzo[k]fluoranthene	-	-	0.006	ND	ND-0.009	ND	ND	-	-	-	ND
Benzo[g,h,i]perylene	-	-	0.006	ND	ND	ND	ND	-	-	-	ND
Benzo[a]pyrene	-	-	0.008	ND	ND	ND	ND	-	-	-	ND
Chrysene	-	-	0.006	ND	ND	ND	ND	-	-	-	ND
Dibenzo[a,h]anthracene	-	-	0.007	ND	ND	ND	ND	-	-	-	ND
Fluoranthene	-	-	0.010	ND	ND-0.020	ND-0.020	ND	-	-	-	ND
Fluorene	-	-	0.016	ND	ND-0.085	ND-0.085	ND	-	-	-	ND
Indeno[1,2,3-cd]pyrene	-	-	0.006	ND	ND	ND	ND	-	-	-	ND
Naphthalene	-	-	0.019	ND-0.020	ND-0.052	ND-0.038	ND	-	-	-	ND
Phenanthrene	-	-	0.012	0.017-0.027	ND-0.084	ND-0.084	ND	-	-	-	ND
Pyrene	-	-	0.008	ND	ND-0.024	ND-0.024	ND	-	-	-	ND

Notes: Data are based on from 5 to 20 samples, depending on contaminant group,area and species
Batchawana Bay: - white sucker.
below Rapids: - pink salmon, chinook salmon, brown bullhead, northern pike,
Lake George: - brown bullhead, smallmouth bass, walleye and yellow perch.
St. Joseph Island: - walleye.
Algoma Mills: - chinook salmon and pink salmon.
Sugar Island: - 9 white sucker (skin on), 3 walley (skin on) and 5 northern pike (skin off) (MDNR 1990).
North Drummond Is.: - 10 yellow perch (skin on) (MDNR 1990).
Lake Munuscong: - 10 northern pike (skin off), 8 walley (skin on) (MDNR 1990).

* Health and Welfare Canada guidelines and/or Great Lakes Water Quality Agreement specific objectives for the protection of human consumers of fish.

' Trigger levels used by the Michigan Department of Public Health (MDPH) in the establishment of fish consumption advisories.

' Dieldrin is included in consumption guideline listed for Aldrin; p,p'-DDT, p,p'-DDD and p,p'-DDE are also included in the guideline for "DDT plus metabolites".

Range minimum to maximum concentration detected.
\- not available
ND not detected at method reporting limit (MRL)

probably lake-run fish which are only in the river during spawning and may have accumulated much of their contaminant burden elsewhere. In contrast, species such as pike, sucker and catfish are more reflective of local contaminant conditions.

Levels of mercury in dorsal fillets of the larger size classes of certain species from the river are presently in excess of the Canadian federal guideline of 0.05 mg/kg (and MDPH trigger level of 0.05 mg/kg) for unlimited consumption by humans. As a result, the Ontario government has issued restricted consumption advisories for larger sizes of longnose sucker, white sucker, walleye, northern pike and lake trout (Table 6.26).

Table 6.26 Ontario long-term fish consumption advisories for the St. Marys River anglers, based on mercury concentration in dorsal fillets (OMOE and OMNR 1991).

Area and Fish Species	Fish Length in Centimetres (inches)							
	20 - 25 (8 - 10)	25 - 30 (10 - 12)	30 - 35 (12 - 14)	35 - 45 (14 - 18)	45 - 55 (18 - 22)	55 - 65 (22 - 26)	65 - 75 (26 - 30)	>75 (>30)
Gros Cap:								
lake trout		NR	NR	NR	NR	NR		
Below Rapids:								
chinook salmon							NR	NR
pink salmon			NR	NR	NR			
rainbow trout	NR	NR	NR	NR	NR			
northern pike					NR	NR	NR	NR
longnose sucker			0.2 kg/wk	0.2 kg/wk				
white sucker			NR	NR	0.2 kg/wk			
walleye			NR	NR	0.2 kg/wk	0.2 kg/wk		
Lake George:								
rainbow trout		NR	NR	NR	NR	NR	NR	
lake trout		NR	NR	NR	NR	0.2 kg/wk		
northern pike			NR	NR	NR	NR	0.2 kg/wk	
white sucker			NR	NR	NR			
walleye		NR	NR	NR	0.2 kg/wk	0.1 kg/wk		
yellow perch	NR	NR	NR					
St. Joseph Channel:								
northern pike						NR	NR	0.2 kg/wk
walleye				NR	NR			
St. Joseph Island area:								
walleye				NR	NR	NR		
whitefish				NR	NR	NR		

Notes: NR = no restrictions (this is the only category that is suitable for consumption by women of childbearing age and by children under the age of 15).

Although the maximum concentration of PCBs in one chinook salmon (2.940 mg/kg) from below the Rapids was above the 2.0 mg/kg federal guideline, levels in the remaining 19 fish were well below the guideline; therefore, this would not necessitate a restricted consumption advisory based on PCB content.

Concentrations of lindane, DDT and its metabolites, heptachlor and toxaphene, when detected in St. Marys River fish, were below their respective guidelines (Table 6.25).

A number of additional contaminants were detected in some of the fish, but in the absence of consumption guidelines and/or upstream data, it is difficult to attach any significance to these concentrations. For example, arsenic, cadmium, chromium, manganese, nickel, selenium and zinc were detected at mg/kg (ppm) or below mg/kg levels in some fish from below the Rapids. Hexachlorobenzene was detected at below mg/kg levels in fish from within the river as well as upstream and downstream. The PAH compounds, naphthalene and phenanthrene were present at below mg/kg levels in fish from below the Rapids and Lake George, but also from upstream Batchawana Bay. However, an additional eight PAH compounds (acenaphthene, acenaphthylene, benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, fluoranthene, fluorene and pyrene) were only found in fish from below the Rapids and Lake George, again at below mg/kg levels (Table 6.25).

Many contaminants were not detected in dorsal fillets of fish from the St. Marys River. These include: lead, aldrin, -BHC, heptachlor, heptachlor epoxide, mirex, oxy-chlordane, trichlorobenzenes, tetrachlorobenzenes, trichlorotoluenes, pentachlorobenzene, chlorostyrenes, trichlorophenols, tetrachlorophenols, terphenyl, pentachlorophenol, polybrominatedbiphenyl, anthracene, benzo(g,h,i)perylene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene and indeno(1,2,3-cd)pyrene.

Sport fish are periodically collected in the St. Marys River and tested regularly by the MDNR. Collections from Sugar Island (1987), Munuscong Lake (1986) and Drummond Island (1989) areas are shown in Table 6.25 (Appendix 6.9). Only larger size fish from Munuscong Lake contained levels of mercury exceeding the MDPH trigger level and the Canadian federal consumption guideline (0.50 mg/kg). α-Chlordane, p,p'-DDT, p,p'-DDE, and cis- and trans-Nonachlor were detected at levels below applicable Canadian guidelines or MDPH trigger levels in fish captured from Michigan waters of the St. Marys River (Table 6.25). The most recent available data are from yellow perch collected from Lake Huron near Drummond Island in 1989. Sample analysis indicated that concentrations of all contaminants were below MDPH trigger levels (Duling and Benzie 1989 and 1990). Additional sampling was conducted in the St. Marys River in 1991 but results were not available.

The MDPH has issued restricted consumption advisories for walleyes larger than 48 cm (19 inches) (See section 4.3.10 for more information on "restricted consumption" and "no consumption" advisories issued by MDPH). In addition, a special advisory has been issued concerning all inland lakes in Michigan due to widespread mercury contamination throughout North Central United States and Canada (MDNR 1991). Kauss (1991), noted that consumption advisories due to mercury have been issued by the Ontario government for walleyes caught in Goulais Bay and for walleye, lake trout and northern pike in Batchawana Bay of Lake Superior (OMOE and OMNR 1991). Therefore, the mercury levels in St. Marys River fish may be due in part to background inputs into the river or into Lake Superior. The contributions of mercury from atmospheric deposition are discussed in Chapter 8.

Fish consumption advisories issued by MDPH for migratory fish captured in Lake Huron also apply to the tributaries into which migratory fish enter. The MDPH has issued a restricted consumption advisory for brown trout less than 53.3 cm (21 inches), lake trout and rainbow trout while issuing a no consumption advisory for brown trout over 53.3 cm (21 inches) taken from Lake Huron. The consumption advisories on these Lake Huron fish were issued because of PCB contamination and apply to the St. Marys River.
Fish have been regularly collected from lower Lake Superior since 1985 by OMOE and OMNR, and a few fish were taken from the North Channel of Lake Huron in 1989. While analyses of the 1989 fish are not yet complete, average PCB levels in edible portions were always less than the Canadian legal limit for PCBs (2.0 mg/kg) in commercial fish. The average concentration of mercury for walleye 50 cm in length was 0.54 mg/kg, just over the 0.5 mg/kg Health and Welfare Canada guideline.

Very little data on contaminant trends are available. What has been analyzed indicates that the mean mercury concentrations in rainbow trout from the St. Marys Rapids area has declined almost 60% between 1978 (0.39 mg/kg wet weight) and 1985 (0.16 mg/kg, wet weight) however, more data are required for statistically analysing this trend (Kauss 1991). Additionally, given the migratory nature of these and other fish, it is difficult to suggest what contribution the St. Marys River is making to their contaminant loads.

The Michigan Department of Natural Resources has investigated incidental reports of tainting and has not found substantive evidence. In 1990, MDNR distributed surveys to a local sportfishing group requesting that any information regarding tainted flavour be documented. There have been no reported incidents of tainting. Because total phenol concentrations have exceeded PWQO (1986 and 1987) and may contribute to the tainting of fish flavour, a more extensive and comprehensive survey is required.

6.7.1.3 Fish Tumours

Information on the incidence of fish tumours or skin diseases (e.g. lymphocystis and dermal sarcoma fibrous, which are both caused by viruses) in the AoC is scarce and ambiguous. This does not mean that tumours are non-existent or unimportant. An investigation by the United States Fish and Wildlife Service indicated that the incidence of liver tumours in *Ictalurus nebulosus* (brown bullheads) taken from Munuscong Bay was as high or higher than one would expect for a control site. The reason(s) for this apparent inconsistency could not be substantiated (Paul Baumann, U.S.FWS, pers. comm.).

A fish tumour survey was conducted by OMOE in the St. Marys River during 1987. White suckers were captured below the Rapids along the Sault Ste. Marie, Ontario shoreline and their livers tested for the presence of mixed function oxidases (MFO), a family of oxygenating enzymes that can be induced by exposure to certain natural and synthetic chemicals. Relative to the upstream control population from Batchawana Bay in Lake Superior, MFO activity in livers of the St. Marys River fish was significantly higher, likely reflecting localized contamination in the sediments, water and benthic invertebrates of the latter area (Smith *et al.*, 1991). An abnormal incidence of liver neoplasms has also been identified in white suckers from the St. Marys River; the frequency was also elevated in suckers from the control population in Batchawana Bay, and this data is being re-evaluated (Smith, OMOE, unpublished data).

6.7.2 Habitat Degradation

As described in Chapter 5, the St. Marys River, and particularly the rapids, have been extensively altered to improve navigation between Lake Superior and Lake Huron, to enhance rail and highway traffic and to provide hydroelectric power. As a result, fish spawning and rearing habitat in the Rapids is subject to dewatering, with attendant adverse impacts on fish habitat, fish fry and benthic macroinvertebrates (Kauss 1991) with a reduction in spawning area and food. Intermittent dewatering may result in the destruction of a variety of fish fry inhabiting the rapids. In 1985 a berm was constructed along the Ontario side of the rapids, parallel to Whitefish Island to maintain a suitable flow rate within the bermed area and Whitefish Channel. However, the water diverted to sustain flows within these areas has dewatered sections of the river bed on the Michigan side and has created inadequate discharge on the Ontario side.

In the lower river, dredging and filling, shoreline development and natural fluctuating water levels have resulted in wetland losses (Krishka 1989) and littoral zone degradation. Industrial development on the river is also felt to have had a negative impact on fisheries habitat through alteration and removal. Other sources of habitat loss or alteration include:

> Permanent residents and cottagers have altered their shorelines to provide better access and docking facilities, often with loss of habitat;
>
> Natural fluctuations in water levels, for example in 1985, the high waters in Lake Huron and Lake Michigan flooded areas of the lower river such that shoreline erosion was observed behind wetlands, and large vegetational mats uprooted and drifted into surrounding waters. The lowest water levels were recorded in 1964-65. Between 1964 and 1985 a difference of approximately 3 metres occurred in the river.
>
> Emergent wetlands and their related fisheries are susceptible to adverse impacts resulting from the passage of commercial and recreational boats. Liston *et al.* (1983) and Poe and Edsall (1982) have shown that drift rates of detritus, macrophytes, zooplankton and macroinvertebrates out of the system are accelerated during ice cover with vessel traffic (winter navigation). In addition, sedimentation and habitat destruction from scouring by vessel-induced wave and current action is accelerated with ice cover (Liston *et al.*, 1983).

Historic log booming in Marks Bay resulted in logs sinking to the sandy bottom where they have become cemented into the sand. Originally the sandy bottom of Marks Bay is somewhat sterile for fish habitat. The logs now act as refuge habitat for invertebrates and small forage fish however, decaying logs can create an anaerobic environment which can destroy fish habitat.

No quantitative estimates of habitat impairment or loss are available for the AoC.

6.7.3 Amphibians and Reptiles

Very little information is available on amphibians and reptiles of the St. Marys River; however, Duffy *et al.* (1987) indicated that 29 species inhabit the river and these are listed in Appendix 6.10.

6.7.4 Summary

The St. Marys River harbours 74 species of fish, many of which are transient or rare. This high number results from the diversity of fish habitats, coupled with introductions and habitat alterations. The current community is primarily a warmwater percid one characterized by walleye, northern pike, yellow perch and white sucker, although coldwater species are also present. A number of species including rainbow smelt, coho salmon, chinook salmon, pink salmon, alewife and sea lamprey, which have been introduced to the Great Lakes basin, either accidentally, intentionally or via gradual invasion from the Atlantic Ocean are found in the AoC. Both the introduced game fish and native game fish provide an important year-round fishery.

In the view of many people, fishing in the St. Marys River has improved since the introduction of the exotic pacific salmon into the Great Lakes mainly because the fish are migrating to and through the river to spawn. Once in the river system they are blocked from further migration upstream by the structures at Sault Ste. Marie. On the other hand, some members of the public feel that the introduction of exotic fish (i.e. salmon) have impaired native fish stocks such as whitefish.

It is speculated that impairment of fish stocks in the St. Marys River has resulted from localized habitat alteration and/or loss, diminished stocks of benthic invertebrates in select areas, overfishing and invasion or introduction of non-native species such as the sea lamprey which is predatory on most larger fish.

The St. Marys River has 6,698 ha of habitat occupied by larval sea lamprey (see section 5.5.5.2). The total potential larval habitat occupied by sea lamprey in all Lake Superior and Lake Ontario tributaries is only 5,392 ha, approximately 80% of the known St. Marys River range (DFO/U.S.FWS, Sea Lamprey Control Office, Data Files). The Lake Huron Technical Committee, 1990, recognizes the St. Marys River as the main source sea lamprey in Lake Huron and realizes that their goal for fish rehabilitation in the lake cannot be achieved until this source is brought under control. They endorsed an objective of a 75% reduction of spawning adults by the year 2000 and a 90% reduction by 2010.

Mercury levels in dorsal fillets of the large size classes of certain species are presently in excess of the Canadian federal guidelines for unlimited consumption by humans or MDPH trigger levels for reduced consumption. The Ontario government has issued consumption advisories for large sizes of longnose sucker, white sucker, walleye, northern pike and lake trout (OMOE and OMNR 1986). The MDPH have issued restricted consumption advisories for walleyes larger than 48 cm (19 inches).

Fish consumption advisories, issued by MDPH for migratory fish captured in Lake Huron, apply to the St. Marys River and any tributary into which migratory fish enter. The MDPH has issued a restricted consumption advisory for brown trout less than 53.3 cm (21 inches), lake trout and rainbow trout while issuing a no consumption advisory for brown trout over 53.3 cm (21 inches) taken from Lake Huron. The consumption advisories on these Lake Huron fish were issued because of PCB contamination.

6.8 WILDLIFE

6.8.1 Birds

As noted in Chapter 5, the St. Marys River and surrounding area support over 180 species of waterfowl, colonial waterbirds, shorebirds, some raptors, and passerines (Appendix 6.11).

6.8.1.1 Production

There is limited production data for birds of the St. Marys River. In 1984, 53 common tern nests on Raber Island produced an average 2.2 young per nest, while nests on Steamboat Island produced 0.43 young per nest. In the same year, the Lime Island common tern colony produced no young in 209 nests, perhaps due to the effects of high water levels and natural and ship-induced wave action (Smith and Heinz, 1984).

The Canadian Wildlife Service conducted waterfowl surveys during the 1987 and 1988 breeding seasons at Pumpkin Point on 4 km^2 plots. The survey showed that the total waterfowl breeding density observed in the wetlands is approximately four times higher than adjacent inland areas (D.R. Fillman, Canadian Wildlife Service, pers. comm.). Table 6.27 shows that densities of breeding pairs of common merganser, red-breasted merganser, gadwall, lesser scaup and Canada goose have decreased from 1987 to 1988.

Table 6.27 1987 and 1988 waterfowl breeding pair survey at Pumpkin Point, St. Marys River (D.R. Fillman, Canadian Wildlife Service, pers. comm.).

Species	Number of Indicated Pairs per 4 km^2	
	1987	1988
Common merganser	2.0	1.0
Red-breasted merganser	2.0	1.0
Mallard	3.0	7.0
Gadwall	1.0	-
Lesser scaup	5.0	-
Common goldeneye	1.0	1.0
Canada goose	4.0	2.0
Loon	-	1.0
Green-winged teal	-	2.0

A marked increase in the number of young produced by osprey and northern bald eagles occurred in the early 1980's. Osprey production increased sharply from 0-5 young per year in 1973-1980 to 15-23 in 1981-1985; in 1986 and 1987, a pair of bald eagles successfully nested on the Munuscong Lake shoreline, producing two young each year (Edsall *et al.*, 1988). This increase suggests that a reduction occurred in the amount of contaminants in the diets of both ospreys and eagles. However, Edsall *et al.* (1988) cautioned that, although the situation appears to be improving, potential threats remain. Increased feeding by osprey and bald eagles on contaminated fish, herring gulls, ring-billed gulls and diving ducks could, for example, compromise the otherwise promising reproductive future for ospreys and bald eagles in the St. Marys River area.

Population trends of ring-billed gulls and common terns, the two most common colonial waterbirds associated with the St. Marys River, have been shifting in recent years. Common terns, once more common than ring-billed gulls, have been declining in numbers, while ring-billed gulls have been increasing. These trends are particularly evident in the St. Marys River, where shipping traffic has accelerated the erosion of dredged material islands. With this loss of habitat, the larger, earlier nesting ring-billed gulls have been displacing common terns and other smaller species from nesting sites (Scharf, 1977, 1978, and 1981 and Scharf and Shugart, 1985).

As reported by Duffy *et al.* (1987), "Double-crested cormorants are also increasing in numbers in the upper Great Lakes, with this population now in the logarithmic phase of growth (Scharf and Shugart, 1985). The success of double-crested cormorants is attributed to an abundant food supply, declines in chlorinated hydrocarbon pollution, and possibly to protected nesting sites".

There also appears to be an increase in the nesting population of greater sandhill cranes. This species nests and feeds in wetlands along the Michigan and Ontario shores, and also inhabits more inland areas on St. Joseph Island and open fields in Chippewa County, Michigan.

6.8.1.2 Contaminants in Birds

As of 1986 the only information on contaminants in birds was a monitoring study carried out from 1984 to 1986 on the eggs of herring gulls and common terns in the Great Lakes Basin. This work is summarized by Kauss (1991) as follows:

> "Due to their habits, some 28 birds species are or could be used as biological monitors in the St. Marys River. Current monitoring is largely focused on such indicators as population stability, fledgling deformities and success, and on eggs, due to the susceptibility of embryos to organochlorine contaminants (Gilbertson 1974), and the effects of these substances on shell thickness (Wiemeyer *et al.*, 1988). Table 6.28 summarizes 1984-86 data on organochlorine contaminants in the eggs of herring gulls and common terns, two piscivorous species that have been routinely used for monitoring in the Great Lakes Basin. It should be noted that these species are not permanent residents of the river, and therefore that contaminant levels in their eggs can reflect exposure of the adult female elsewhere. Mean concentrations of PCBs, *p,p'*-DDE and 2,3,7,8-tetrachlorodibenzo-p-dioxin in herring gulls eggs from the St. Marys River colony, while elevated, are typical of other areas of the Great Lakes (i.e., upstream Lake Superior) or in the background range. Mean levels of total PCBs and *p,p'*-DDE were less in common tern eggs from the lower river than in herring gull eggs from Lake George. However, the highest individual PCB concentration in the former (7.3 mg/kg) was within the range that could produce harmful effects in eggs (Edsall *et al.*, 1988). These contaminant levels may also pose a threat to higher trophic levels (i.e., ospreys and bald eagles), particularly in the case of gulls which are increasing in numbers" (see Figure 5.13 in Chapter 5)".

A study investigating contaminant levels in breast meat of waterfowl collected along the St. Marys River was carried out by the Canadian Fish and Wildlife Service from the fall of 1988 to the fall of 1990. Results from this survey are shown in Table 6.29. These data should be treated with caution because samples were collected during the migration period and are by no means an indication of point source contamination. However, these data do indicate the level of contaminants in waterfowl that could be consumed by hunters.

Concentrations of mercury in breast meat ranged from 0.13 to 0.46 mg/kg with the highest values in common mergansers (Table 6.29). Most pesticides and herbicides were either not detected or very low.
Concentrations of aroclor (PCBs) were detected in all waterfowl sampled with values ranging from 0.002 to 4.873 mg/kg. Because there are no criterion for contaminants in birds the significance of these results is not known.

Table 6.28 Organochlorine contaminants in eggs of piscivorous birds in Lake Superior and the St. Marys River, 1984-1986 (Kauss 1991).

Species	Location	Contaminant	Mean Concentration (mg/kg, wet weight)	Source
Herring Gull	Agawa Rock (Lake Superior)	p,p'-DDE	3.0/3.1	a
		Total PCBs	12.0/14.0	a
		1,2,3,4-TeCB	0.007/NA	a
	Pumpkin Point, Lake George (St. Marys River)	p,p'-DDE	4.0/3.2	a
		Total PCBs	22.0/14.0	a
		1,2,3,4-TeCB	0.003/NA	a
		2,3,7,8-TCDD	$4\ 10^{-6}/16\ 10^{-6}$	a
Common Tern	Lime Island (lower St. Marys River)	p,p'-DDE	1.8	b
		Total PCBs	3.9	b

Notes: NA - Not available
TeCB - tetrachlorobenzene
TCDD - tetrachlorodibenzo-p-dioxin

Source: a - Canada Wildlife Service (unpublished data for 1985/1986, C.V. Weseloh, pers. comm. April, 1988)
b - U.S. Fish and Wildlife Service (unpublished data for 1984 in Edsall *et al.*, 1988)

6.8.2 Mammals

In total, 59 species of mammals have been recorded from the St. Marys River and its immediate environs (Appendix 6.12).

6.8.2.1 Contaminants in Mammals

Limited data are available on contaminant levels in mammals specific to the AoC. However, recent investigations throughout Ontario by the OMNR have identified high levels of cadmium in the kidneys and to a lesser extent, in the liver of moose, black bear and deer. Cadmium also showed a tendency to bioaccumulate with older animals having higher levels than the younger ones (OMNR News Release, October 20, 1988). The high cadmium levels were not specific to the AoC and a Province wide advisory was issued.

Table 6.29 Concentrations of organochlorine contaminants and metals found in breast muscles of waterfowl captured in the St. Marys River AOC from the fall of 1988 to the fall of 1990 (Canadian Wildlife Service, unpublished data).

Species	Black Duck	Mallard	Wood Duck	Common Goldeneye	Common Goldeneye	Common Merganser	Common Merganser	Hooded Merganser	Hooded Merganser	Red-breasted Merganser
Age	5Ad	5Ad	1Ad	2Ad	1Im	1Ad	3Ad	1Ad	1Im,1Ad	1Ad
Sex	3F, 2M	2F,3M	1M	2M	1M	1M	2F,1M	1F	3F,1M	1F
Number	5	5	1	2	1	1	3	1	4	1
Location	Carp Lake SSM	Pumpkin Pt	Carp Lake SSM	Echo R., SSM	St Marys R.	Lower Echo R., SSM	SSM	St Marys R.	SSM	SSM
% Lipid	1.82	1.66	2.64	2.88	4.460	3.97	3.440	2.210	3.010	3.140
% Water	72.65	72.57	72.81	72.64	69.970	71.41	72.030	73.490	72.920	71.990
Cd (0.02)*	<0.02			0.02		<0.02				
As (0.10)*	<0.20			<0.20		<0.02				
Pb (0.02)*	<0.20			<0.20		<0.02				
Se (0.10)*	<0.20			<0.20		0.90				
Total Hg (0.05)*	0.13			0.12		0.46				
1,2,4,5-T4CB	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,3,4-T4CB	ND	ND	ND	ND	ND	0.002	ND	ND	ND	ND
QCB	ND	ND	ND	ND	ND	0.002	ND	ND	ND	ND
HCB	ND	ND	ND	0.004	ND	0.023	0.0016	ND	ND	0.0022
a-HCH	ND	ND	ND	ND	ND	0.002	0.0013	ND	ND	ND
b-HCH	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
g-HCH	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
OCS	ND	ND	ND	ND	ND	0.033	ND	ND	ND	0.0011
oxy-Chlordane	ND	ND	ND	0.005	ND	0.014	0.0015	0.0012	ND	0.0069
trans-Chlordane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
cis-Chlordane	ND	ND	ND	ND	ND	0.002	ND	ND	ND	ND
trans'nonachlor	ND	ND	ND	0.002	ND	0.013	0.0016	ND	ND	ND
cis-nonachlor	ND	ND	ND	ND	ND	0.006	ND	ND	ND	ND
pp'-DDE	ND	0.002	ND	0.104	0.0018	0.643	0.0303	0.0385	0.0182	0.2643
pp'-DDD	ND	ND	ND	0.001	ND	0.007	ND	ND	ND	ND
pp'-DDT	ND	ND	ND	ND	ND	ND	0.0021	ND	ND	0.0013
Photo-mirex	ND	ND	ND	0.003	ND	ND	0.0034	0.0014	ND	0.0145
Mirex	ND	ND	ND	0.010	ND	0.003	ND	0.0011	0.0037	0.0120
HE	ND	ND	ND	0.003	ND	0.019	0.0018	ND	ND	0.0043
Dieldrin	ND	ND	ND	0.009	ND	0.052	ND	ND	ND	0.0049
Aroclor (PCBs)	0.002	0.006	0.002	0.308	0.003	4.873	0.377	0.134	0.042	0.919

* Nominal detection limits
Im - Immature; Ad - adult; F - female; M - male; U - unknown
ND = <0.001 mg/kg wet wt. Blanks indicate not analyzed for that parameter
SSM - Sault Ste. Marie

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7 ENVIRONMENTAL CONCERNS/USE IMPAIRMENT

7.1 INTRODUCTION

The objective of this chapter is to summarize the use impairments and water, sediment and biota quality problems described in Chapter 6 (Environmental Conditions). Annex 2 of the Great Lakes Water Quality Agreement of 1978, as amended in 1987, defines 'Impairment of Beneficial Use(s)' as "...a change in the chemical, physical or biological integrity of the Great Lakes System sufficient to cause and of the following:

- (i) Restrictions on fish and wildlife consumption;
- (ii) Tainting of fish and wildlife flavour;
- (iii) Degradation of fish and wildlife populations;
- (iv) Fish tumours or other deformities;
- (v) Bird or animal deformities or reproduction problems;
- (vi) Degradation of benthos;
- (vii) Restrictions on dredging activities;
- (viii) Eutrophication or undesirable algae;
- (ix) Restrictions on drinking water consumption, or taste and odour problems;
- (x) Beach closings;
- (xi) Degradation of aesthetics;
- (xii) Added costs to agriculture or industry;
- (xiii) Degradation of phytoplankton and zooplankton populations; and
- (xiv) Loss of fish and wildlife habitat."

Several of these use impairment categories are divided into subcategories for discussion purposes in this chapter to more clearly define the scope of the problems in the St. Marys River AoC. For example, 'restrictions on fish and wildlife consumption' is divided into 'restrictions on fish consumption' and 'restrictions on wildlife consumption'.

A determination as to whether a specific use impairment exists in the St. Marys River AoC was made using the Listing/Delisting Guidelines (Appendix 2.1) for Great Lakes Areas of Concern in conjunction with applicable standards, guidelines and objectives where available. In the absence of standards, guidelines or objectives, impairment status is based on best professional judgement from the evidence available. The status of beneficial uses as well as exceedences of ambient standards, guidelines and objectives are summarized in Table 7.1.

7.2 USE IMPAIRMENTS

7.2.1 Restrictions on Fish and Wildlife Consumption

7.2.1.1 Restrictions on Fish Consumption

Contaminant levels in dorsal fillets of adult sport fish (1986, 1987 and 1989) from Ontario and Michigan waters in the St. Marys River Area of Concern are similar and, except for mercury, below applicable Health and Welfare Canada guidelines and Michigan Department of Public Health trigger levels. Levels of mercury exceeded both the Canadian and MDPH guideline and trigger level (0.5 mg/kg) in fish captured in Ontario waters downstream of the Rapids and in Michigan waters in Munuscong Lake.

Table 7.1 Summary of Great Lakes Water Quality Agreement beneficial uses and their significance and impairment status with regard to the St. Marys River Area of Concern.

GLWQA Beneficial Use	Status	Significance to St. Marys River
Restrictions on Fish and Wildlife Consumption		
Restrictions on Fish Consumption	Impaired	Fish consumption advisories are currently in effect: **Ontario** mercury: larger sizes of longnose sucker, white sucker, walleye, northern pike and lake trout **Michigan** mercury: St. Marys River walleye in excess of 48 cm (19 inches) PCBs: restricted consumption of brown trout, lake trout and rainbow trout from Lake Huron and tributaries
Consumption of Wildlife		Although there are no guidelines for human consumption, OMNR has advised against the consumption of kidneys and liver from moose, black bear and deer because of high cadmium levels for the entire Province of Ontario.
Tainting of Fish and Wildlife Flavour	Requires assessment	Although there have been no confirmed reports of tainted fish flavour, phenol concentrations at levels which may cause tainting, have been detected. A comprehensive study is required to evaluate the status of this beneficial use.
Degradation of Fish and Wildlife Populations	Impaired	
Dynamics of Fish Populations		Large populations of sea lamprey are contributing to the mortality of large migratory fish such as salmon. 1986 through 1990 records indicate 40 - 60 lamprey wounds for every 100 salmon taken. Fish fauna are diverse and healthy however, populations of native fish have been reduced and assemblages have changed due to habitat alteration, overfishing, pollution and stocking.
Body burdens		Low levels of PCBs, chlordane, BHC and DDT have been found in juvenile yellow perch and spottail shiners. Adult fish contaminants include mercury, PCBs, and detectable levels of chlordane, DDT, BHC, nonachlors, dieldrin, pentachlorobenzene, hexachlorobenzene and octachlorostyrene. Effects of these chemicals on fish are not known.
Dynamics of Wildlife Populations		Wildlife populations appear to be stable or increasing (i.e. double-breasted cormorants) but assessment criteria is required. Common tern populations are decreasing while ring-billed gull populations increase due to a decline in nesting habitat.
Body burdens of Wildlife		Mercury concentrations in waterfowl breast meat ranged from 0.12 to 0.46; aroclor (PCBs), detected in all specimens, ranged from 0.002 to 4.873 mg/kg; however there is no criteria available for assessment.
Fish Tumours and Other Deformities	Impaired	Impaired due to the incidence of liver tumours in brown bullheads from Munuscong Bay. White suckers, captured downstream of the Rapids along the Ontario shore in 1987, showed siginificantly higer levels of mixed function oxidases (MFO) in their livers than did fish captured in Lake Superior. This is likely due to contaminants in the St. Marys River water, sediment and benthos.

Table 1.1 (Cont'd)

GLWQA Beneficial Use	Status	Significance to St. Marys River
Bird and Animal Deformities or Reproductive Problems	Not Impaired	Bird or animal deformities have not been found in the St. Marys River AoC nor have reproductive problems been reported.
Degradation of Benthos Dynamics of Benthic Populations	Impaired	Benthic community health is good on the Michigan side of the river. Benthic communities are moderately impaired on the Ontario side from the Algoma Slag Site downstream 4 km. Impairment also occurs on both sides of the Lake George Channel. within Little Lake George and the north end of Lake George.
Body burdens of Benthic Organisms		Arsenic, mercury and PCBs tend to bioaccumulate in benthic organisms. Caged mussels placed downstream of the Algoma Slip acquired the highest total PAH levels. Total PAH levels were low in mussels placed upstream of the Algoma Slip and near the Michigan shore. The effects of these contaminants on benthic organisms is not known.
Restrictions on Dredging Activities	Impaired	Contaminated dredge spoils from the Algoma Slip must be disposed of on an upland waste site. Dredge spoils from navigation channels have always been approved for open water disposal. Sediments from the following sites: downstream of the Algoma Slag Site along the Ontario shore; on both sides of the Lake George Channel; Little Lake George; the northern half of Lake George; the Michigan shore adjacent to the Cannelton Industries waste site; the head of the St. Joseph and West Neebish Channels; and Lake Munuscong had contaminant levels that exceeded OMOE guidelines or U.S.EPA guidelines for the disposal of contaminated sediment.
Eutrophication or Undesirable Algae	Impaired	Citizens have reported excessive amounts of algae in embayments and slow moving parts of the river downstream of the East End WPCP. Open waters of the St. Marys River reflect the oligotrophic (nutrient poor) character of Lake Superior waters. Conditions in embayments and slow moving areas of the river have not been documented.
Restrictions on Drinking Water Consumption or Taste and Odour Problems Consumption	Not Impaired	Treated water consumption from municipal sources has never been restricted however, ambient conditions in the water restrict consumption prior to treatment.
Taste and Odour Problems		Taste and odour problems have not been reported.
Ambient Water Quality	Impaired	Exceedence of ambient water quality criteria in the St. Marys River. Localized impairment. Exceedences of criteria for dissolved oxygen, turbidity, phenols, total and unionized ammonia, iron, total phosphorus, PAHs and bacteria occur downstream of Ontario discharges. Cyanide exceedences were not recorded in the 1986/87 OMOE survey.

Table 7.1 (cont'd)

GLWQA Beneficial Use	Status	Significance to St. Marys River
Beach Closings and Body Contact	Impaired	In Michigan, total body contact activities are periodically impaired due to elevated bacteria levels. Bacterial densities have exceeded PWQO and MWQS.
Degradation of Aesthetics	Impaired	Oil slicks downstream of the Algoma Slip and Terminal Basin have occurred. Floating scums periodically occur along the north shore of Sugar Island, the Ontario shoreline of Lake George Channel and downstream. Oily fibrous material mixed with woody material periodically occur along the Ontario shoreline.
Added Cost to Agriculture and Industry	Not Impaired	None documented.
Degradation of Phytoplankton and Zooplankton Populations	Not Impaired in open water	Open water community structure and densities reflect Lake Superior. Communities in embayments and other slow-moving areas require further assessment because of impaired ambient water quality.
Loss of Fish and Wildlife Habitat	Impaired	Significant loss of fish and wildlife habitat have occurred as a result of shoreline alteration, industrialization, urbanization and shipping activities particularly in the St. Marys Rapids.

As a result, the Ontario government has issued restricted consumption advisories for larger sizes of longnose sucker, white sucker, walleye, northern pike and lake trout. The MDPH has issued a consumption advisory for walleyes larger than 48 cm (19 inches).

Michigan fish consumption advisories for Lake Huron also apply to tributaries into which migratory fish enter. The MDPH has issued a restricted consumption advisory for brown trout less than 53.3 cm (21 inches), lake trout and rainbow trout while issuing a no consumption advisory for brown trout over 53.3 cm (21 inches) taken from Lake Huron. The consumption advisories on these Lake Huron fish were issued because of PCB contamination and apply to the St. Marys River.

This beneficial use is impaired.

7.2.1.2 Restrictions on Wildlife Consumption

There are no formal advisories currently in place for the consumption of wildlife by humans. The Ontario Ministry of Natural Resources has recommended a Province wide consumption restriction of kidneys and liver from moose, black bear and deer because of high levels of cadmium.

7.2.2 Tainting of Fish and Wildlife Flavour

The Michigan Department of Natural Resources has investigated incidental reports of tainting and has not found substantive evidence. A 1990 MDNR survey, conducted with local sport fishermen, reported no incidents of tainted fish. However, total phenol concentrations have exceeded PWQO (1986 and 1987) and may contribute to the tainting of fish flavour.

This beneficial use requires further assessment.

7.2.3 Degradation of Fish and Wildlife Populations

7.2.3.1 Dynamics of Fish populations

The increasing population of adult spawning sea lamprey in the St. Marys River suggests that sea lamprey are contributing to the increased mortality of fish, particularly salmon and lake trout in Lakes Huron and Superior. Migratory species such as salmon show a high incidence of wounds (40-60 wounds per 100 fish, 1986-1990). The St. Marys River has become a major spawning ground for sea lamprey and the chemical treatment of lamprey larvae will be difficult and expensive due to the rivers large size.

The fish community in the St.Marys River is diverse and includes 74 species of warm, cool and coldwater fish. Harvest and catch per unit effort (CUE) have improved in recent years as a result of the introduction of exotic species including pink and chinook salmon and rainbow trout. Stocking of Atlantic salmon, chinook salmon, rainbow trout, brown trout, walleye and lake trout by MDNR and chinook salmon, rainbow trout and brown trout from municipal hatcheries in Sault Ste. Marie, Ontario, have contributed to the fishery. Populations of native species such as lake whitefish and lake herring have declined due to overfishing.

Population reductions are suspected due to alteration of fish spawning habitat through alteration of the Rapids and dredging and filling throughout the AoC. Overfishing, exotic species and decreases in benthos populations may also affect fish populations.

Although the fish populations appear to be healthy, public concerns are now being raised suggesting that native fish populations, such as lake whitefish and lake herring, are declining because of the introduction of non-indigenous species. Stocking efforts concentrate mainly on the introduced species, such as salmon and rainbow and brown trout, for sport fishing and native fish species are taken by tribal commercial and subsistence fishing. Quantitative data supporting this concern is not available and it is not known what impact the exotic species have on native species habitat.

This beneficial use is impaired.

7.2.3.2 Body Burdens of Fish

Analysis of whole, young-of-the-year yellow perch and spottail shiners (which are routinely sampled to assist in pinpointing sources of contamination) have shown that levels of PCBs, chlordane, BHC, DDT and its metabolites, mirex, and chlorinated benzenes, aliphatics and phenols are either not detected or below the GLWQA objectives for the protection of birds and animals which consume fish (Section 6.7.1.2). PCBs in adult white sucker and carp from the St. Marys and Tahquamenon Rivers are above the GLWQA objective.

7.2.3.3 Dynamics of Wildlife Populations

Wetlands around the St. Marys River are significant staging grounds for waterfowl such as mallards, common mergansers, common goldeneye, black ducks, blue- and green-winged teal and the american widgeon. The river is also a main corridor for dabbling ducks and a variety of migrating waterfowl. Population changes in waterfowl have not been assessed.

Ring-billed gulls and common terns are the two most common colonial waterbirds within the St. Marys River Area of Concern. Populations of common terns, once more common than ring-billed gulls, have been declining while ring-billed gull populations have been increasing. This trend is most evident where shipping traffic has accelerated the erosion of dredged material islands, hence decreasing nesting habitat. The earlier nesting and larger ring-billed gulls have been replacing the common terns in a competition for nesting habitat.

Populations of double-crested cormorants have increased logarithmicaly due to an abundant food supply, declines in chlorinated hydrocarbon pollution and possibly protected nesting sites (Duffy *et al.*, 1987). Other waterbird populations, i.e. black terns and great blue herons, appear to be stable.

The number of young produced by osprey and bald eagles in the St. Marys River AoC have increased in recent years. However, Edsall *et al.* (1988) caution that because they may feed on contaminated fish, herring gulls, ring-billed gulls and diving ducks, their reproductive future is still in jeopardy.

The St. Marys River AoC also provides excellent habitat for amphibians reptiles and mammals. Population changes in these other wildlife groups have not been assessed.

7.2.3.4 Body Burdens of Wildlife

Kauss (1991) states that approximately 28 bird species are or could be used as biological monitors in the St. Marys River. Monitoring in the St. Marys River AoC presently focuses only on the organochlorine contaminants in the eggs of herring gulls and common terns (See section 7.2.5).

Concentrations of mercury in breast meat ranged from 0.13 to 0.46 mg/kg with the highest values in common mergansers. Most pesticides and herbicides were either not detected or very low. Concentrations of aroclor (PCBs) were detected in all waterfowl sampled with values ranging from 0.002 to 4.873 mg/kg. Because there are no criterion for contaminants in birds the significance of these results is not known.

7.2.4 Fish Tumours or Other Deformities

Information on the incidence of fish tumours or skin diseases (e.g. lymphocystis and dermal sarcoma/fibrous, which are both caused by viruses) in the AoC is scarce and ambiguous. An investigation by the United States Fish and Wildlife Service indicated that the incidence of liver tumours in brown bullheads from Munuscong Bay was higher than would be expected for a control site (Paul Baumann, U.S.FWS, pers. comm.). An explanation for this anomaly could not be determined.

A fish tumour survey was conducted by OMOE in the St. Marys River during 1987. White suckers captured below the Rapids along the Ontario shoreline showed significantly higher mixed function oxidases (MFO) in their livers (oxygenating enzymes induced by exposure to certain chemicals) than fish captured from Batchawana Bay (control site) in Lake Superior. This increase likely reflects localized contamination in the sediments, water and benthic invertebrates of the St. Marys River (Smith *et al.*, 1991). An abnormal incidence of liver neoplasms has also been identified in white suckers from the St. Marys River; however, the frequency was also elevated in suckers from the control population in Batchawana Bay. This data is being re-evaluated (Smith, OMOE, unpublished data).

This beneficial use is impaired.

7.2.5 Bird or Animal Deformities or Reproduction Problems

Bird or animal deformities have not been found in the St. Marys River AoC, nor have reproduction problems been reported.

A 1984-86 survey of organochlorine contaminants in the eggs of herring gulls and common terns, two piscivorous species that have been routinely used for monitoring in the Great Lakes Basin, found that mean concentrations of PCBs, *p,p'*-DDE and 2,3,7,8-tetrachlorodibenzo-p-dioxin in herring gulls eggs from the St. Marys River were elevated but are typical of other areas of the Great Lakes (i.e., upstream Lake Superior). Mean levels of total PCBs and *p,p'*-DDE were less in common tern eggs from the lower river than in herring gull eggs from Lake George. However, the highest individual PCB concentration in the former (7.3 mg/kg) was within the range that could produce harmful effects in eggs (Edsall *et al.*, 1988). It must be noted that herring gulls and common terns are not permanent residents of the river and that contaminant levels in their eggs may reflect exposure of the adult female elsewhere.

This beneficial use is not impaired.

7.2.6 Degradation of Benthos

7.2.6.1 Dynamics of Benthic Populations

Burt *et al.* (1988), demonstrated that industrial and municipal discharges severely impacted the benthic macroinvertebrate communities in the Algoma Slip and in downstream embayments along the Ontario shoreline. Moderate impairment was generally restricted to a narrow band approximately 500 m wide, extending 4 km along the Ontario shore downstream of the industrial discharges. Some recovery was apparent about 5 km downstream from the Algoma Steel and St. Marys Paper discharges however, complete recovery did not occur until the lower section of Lake George, some 24 km downstream from these discharges. Clean water (unimpaired) fauna characterized the non-industrialized Michigan shore, the entire river upstream of pollutant sources, and Lake Nicolet.

Despite considerable reductions in various contaminant concentrations in the river including phenols, ammonia, oil and grease, cyanide, etc., substantial improvements have not been observed in the AOC's benthic communities. Sediments continuing to have visible oily residues are characterized by low numbers or the complete absence of larvae of the burrowing mayfly *Hexagenia limbata*. Populations of *Hexagenia limbata*, an important food source for several fish species, are also depressed by high concentrations of oil, cyanide and heavy metals in sediment.

This beneficial use is impaired.

7.2.6.2 Body Burdens of Benthic Organisms

Sediments heavily contaminated with heavy metals are generally considered to affect benthic organisms, either by completely eliminating communities or by reducing their diversity or productivity. Metal concentrations in sediment-dwelling organisms (tubificids) generally correlate poorly with concentrations sediment. With the exception of arsenic and mercury, historical and current loads do not appear to be accumulating in benthic organisms in the St. Marys River. Arsenic and mercury are the only metals that appear to be bioaccumulating in benthic organisms.

Organic contaminant accumulation was generally low, with only some of the more persistent organics (PCBs) accumulating in organic tissues of benthic organisms. However, mussels exposed to river water near and downstream of Ontario industrial and municipal discharges accumulated higher levels of certain PAH compounds than did mussels located upstream of the discharges. PAH accumulations in mussels located along the Michigan shoreline were generally lower than those near the Ontario shore. Mussels exposed near the Algoma Slip had the highest PAH levels. Nevertheless, concentrations of benzo(a)pyrene were well below the proposed IJC objective of 1 mg/kg for organisms serving as a food source for fish.

7.2.7 Restrictions on Dredging Activities

Dredge spoils from the navigation channel have always been approved for open water disposal (USACOE Data Files). Sediments dredged from the Algoma Slip are disposed of on upland facilities. Contaminants in sediments from the Algoma Slip exceed the most stringent Ontario OWDG or "moderately polluted" U.S. EPA guidelines for dredged materials. These contaminants include iron, zinc, cyanide and oil and grease. In addition, total PAHs exceeded the proposed Ontario Sediment Quality Guideline of 2.0 mg/kg.

Sediments downstream of the Algoma Slip and along the Ontario shore, in Little Lake George and Lake George exceeded guidelines for dredged materials (OWDG and U.S. EPA) for iron, chromium, zinc, lead, arsenic, manganese, nickel, copper, oil and grease, PCBs, LOI, total phosphorus and TKN. Total PAHs exceeded the proposed Ontario Sediment Quality Guideline at these locations.

Lake Nicolet exceedences included iron, chromium, zinc, lead, arsenic, manganese, nickel, copper, cadmium, oil and grease, PCBs, LOI, total phosphorus, and TKN. Chromium, nickel, copper, mercury (one sample), and PCBs were exceeded in Munuscong Lake. Chromium and cadmium exceedences occur at the head of the St. Marys River along the Michigan shore at the Cannelton Industries waste disposal site.

Naturally occurring copper and chromium in bedrock and soils contribute to levels found in St. Marys River sediment. 1987 background concentrations from Marks Bay exceed the U.S. EPA moderately polluted guideline.

This beneficial use is impaired.

7.2.8 Eutrophication or Undesirable Algae

Most of the available information is based on open water areas of the St. Marys River where residence time is short. Lake Superior is the source of most of the St. Marys River water, phytoplankton, with diatoms, chlorophytes and chrysophytes dominating both water bodies. The most important larger phytoplankton species are typical of oligotrophic (nutrient poor) waters.

Although waters of the St. Marys River reflect the oligotrophic character of Lake Superior, total phosphorus guidelines have been exceeded along the Ontario shoreline downstream of the East End WPCP. The addition of total phosphorus can cause rapid algal growth and citizens have reported excessive amounts of algae in embayments and slow-moving parts of the river. During the summer of 1990, OMOE received a number of citizens' complaints regarding floating algae on the river below the East End WPCP.

This beneficial use is locally impaired.

7.2.9 Restrictions on Drinking Water Consumption or Taste and Odour Problems

7.2.9.1 Consumption

In Michigan, ambient water quality conditions do not restrict use of the St. Marys River, subsequent to standard treatment, as a source of potable water. The City of Sault Ste. Marie, Ontario now obtains approximately 50% of its drinking water from an intake located in near-shore Lake Superior at Gros Cap, upstream of point source discharges. Drinking water is also obtained from city wells. There have been no instances in Sault Ste. Marie, Ontario where restrictions have been implemented by the Algoma Health Unit for the consumption of treated drinking water (Wes Terry, Algoma Health Unit, pers. comm.) however, federal, state and local agencies advise against the consumption of surface water prior to standard treatment.

This beneficial use is not impaired.

7.2.9.2 Tastes and Odour Problems

Densities of blue-green or chrysophytic algae and concentrations of phenolic compounds do not occur at levels which would adversely affect taste and odour of treated drinking water. Taste and odour problems have not been reported for St. Marys River water.

7.2.10 Impairment of Ambient Water Quality

Ambient water quality criteria have been exceeded in the St. Marys River. Exceedences of dissolved oxygen, turbidity, phenols, total and unionized ammonia, cyanide, iron, total phosphorus, PAHs and bacteria have been documented downstream of Ontario industrial and municipal discharges along the Ontario shoreline. 1986/87 sampling indicates that cyanide levels were below the PWQO and MWQS criteria. Levels of bacteria and phenols showed exceedences in Michigan waters downstream of the locks. Bacterial densities, total phosphorus and free and unionized ammonia exceeded PWQO and MWQS downstream of the East End WPCP in the Lake George Channel.

This beneficial use is impaired.

7.2.11 Beach Closings and Body Contact

In Michigan, total body contact advisories against swimming and bathing were periodically issued in 1989 by the Chippewa County Health Department in response to elevated fecal coliform levels caused by combined storm sewer overflows, however, no beaches have been closed. The Sherman Park Beach, located at the head of river upstream of all discharges, and the Sugar Island Township Park beach located on the northwest shore of Sugar Island, have never been closed and high levels of bacteria have not been found.

Fecal coliform bacterial densities in excess of the PWQO and MWQS occur in Ontario and Michigan waters downstream of storm sewers, combined sewer overflows (Michigan), industrial outfalls and the East End WPCP (Ontario).

This beneficial use is impaired.

7.2.12 Degradation of Aesthetics

Floating scum along the north shore of Sugar Island in Michigan is periodically reported. In Ontario, mats of oily fibrous material mixed with wood chips occasionally occur between Sault Ste. Marie and the Lake George Channel. As well, oil slicks appear from time to time downstream from the Algoma Slip and Terminal Basin. Since March 1990, no complaints of floating oil have been received. This may be a result of improvements made at Algoma Steel (G. LaHaye, OMOE, pers. comm.).

This beneficial use is impaired.

7.2.13 Added Cost to Agriculture or Industry

When additional costs are required to treat water prior to use for agricultural or industrial purposes, this use category is considered to be impaired.

In both Michigan and Ontario, no additional treatment costs to current agricultural and industrial users have been identified, consequently, impairment is unlikely.

This beneficial use is not impaired.

7.2.14 Degradation of Phytoplankton and Zooplankton Populations

In open water phytoplankton and zooplankton populations are low in terms of abundance and relatively diverse in terms of community structure and reflect the oligotrophic characteristics of Lake Superior waters.

Phytoplankton and zooplankton populations have not been documented in nearshore areas of the St. Marys River where waters are slow moving and residence is long. There is no information to determine if plankton populations are impaired by contaminants. An assessment of plankton in embayments and slow-moving waters is required because of impaired ambient water quality.

This beneficial use is not impaired in open water.

7.2.15 Loss of Fish and Wildlife Habitat

Fish habitat, particularly in the St. Marys Rapids, has been altered over the past century through the construction of locks, power canals, hydroelectric facilities, compensating works, shoreline infilling and dredging. As a result, fish spawning and rearing habitat in the Rapids is subject to dewatering, with attendant adverse impacts on fish habitat mostly in a reduction of spawning area and food supply (Kauss 1991). In 1985 a berm was constructed along the Ontario side of the rapids, parallel to Whitefish Island to maintain a suitable flow rate within the bermed area and Whitefish Channel. However, the water diverted to sustain flows within these areas has dewatered sections of the river bed on the Michigan side and has created inadequate discharge on the Ontario side.

Industrial development on the Ontario side of the river is also felt to have had a negative impact on fisheries habitat through alteration and removal of benthic communities which are a food source for fish.

In the lower river, dredging and filling, shoreline development and natural fluctuating water levels have resulted in wetland losses (Krishka 1989) and littoral zone degradation resulting in loss of fish and wildlife habitat.

On-going aggregate extraction in Whitefish Bay of Lake Superior is being monitored to determine impacts on whitefish spawning grounds.

Agricultural practices, deforestation and road building affect water quality and quantity and physical fish habitat in the tributaries in the catchment due to sedimentation, stream bank alteration, increases in water temperature and decreases in flows during mid summer and winter. These tributaries are often important spawning and nursery habitat for game fish such as sturgeon, trout, salmon and walleye (J. Atkinson, OMNR, pers. comm.)

Emergent wetlands and their related fisheries and wildlife may be susceptible to adverse impacts resulting from the passage of commercial and recreational boats and the associated changes in current direction and velocity.

This beneficial use is impaired. Fish and wildlife management plans are needed so that the scope of impairment can be determined in order to develop habitat goals.

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8 SOURCES AND LOADS

8.1 INTRODUCTION

Factors impacting on water quality, sediment and biota in the St. Marys River Area of Concern (AoC) relate primarily to contaminants contributed via point sources and non-point sources and human activities such as shipping and water level regulation over the Rapids. Direct point sources are defined as those facilities that discharge their effluents directly into the St. Marys River via man-made pipes and sewers. These point sources include both municipal sewage treatment facilities and industrial process or waste streams. Non-point sources are diffuse inputs which reach the river from multiple points of origin via natural and man-made delivery mechanisms. These non-point include atmospheric deposition, intermittent stormwater discharges, combined sewer overflows, rural land runoff, navigation, groundwater migration (including contributions from waste disposal sites) and release from bottom sediments.

Contaminants of concern for the St. Marys River AoC were identified in Chapter 6 on the basis of known impacts to water quality, sediment or biota based on guideline exceedences or biotic impairment. These contaminants include conventional, organic and inorganic parameters for which sources are known in the St. Marys River Area of Concern. The primary contaminants of concern are:

Conventional/Inorganic Contaminants:

- cyanide
- ammonia-N
- bacteria
- total phosphorus
- LOI
- TKN
- oil and grease
- arsenic
- cadmium
- chromium
- copper
- iron
- lead
- manganese
- mercury
- nickel
- zinc

Organic Contaminants:

- total phenols
- total PAHs
- PCBs

Other Exceedences:

- dissolved oxygen
- turbidity

In summarizing sources of contaminants to the St. Marys River, the UGLCCS (1988) concluded that Algoma Steel, St. Marys Paper and the East End and West End Water Pollution Control Plants (WPCP) on the Ontario side of the river were the major point sources of individual contaminants. Atmospheric inputs, urban runoff, Bennett and East Davignon Creeks, and four waste sites (Algoma Slag Site, Cannelton Industries Site, Superior Station 3 Mile Site and the Union Carbide Site) were identified as major or potential non-point sources of contaminants. The 753 Radar Station area is a site of environmental concern.

8.2 POINT SOURCES

Major Ontario point sources to the St. Marys River AoC include the effluent from two municipal Water Pollution Control Plants (WPCP); and two major industrial facilities representing the iron and steel and pulp and paper sectors (Figure 8.1). The point source data available for review at the time of writing, consists of the 1986 data reported in the UGLCCS (1988) final report as well as 1988 self-monitoring data and industrial dischargers reports (OMOE 1989a and b). Data for 1989 for the Ontario WPCPs are also included.

The only major Michigan point source is the Sault Ste. Marie, Michigan Wastewater Treatment Plant (WWTP) (Figure 8.1). Compliance monitoring data are available for recent years including 1990.

8.2.1 Municipal Point Sources

8.2.1.1 Ontario

The municipal WPCPs which discharge directly to the AoC, are the Sault Ste Marie (East End) WPCP and the West End WPCP. Loadings data are available for these facilities from 1984 through 1989 for BOD5, suspended solids and total phosphorus (OMOE 1985, 1986, 1987, 1988, 1989a and 1990a). Earlier data for BOD5 and total phosphorus were reported in UGLCCS (1988). The WPCPs serve a combined urban population of about 85,000 people.

The Sault Ste Marie (East End) WPCP is a primary treatment facility. Continuous phosphorus removal via chemical treatment was added to the plant in April of 1989. It discharges directly to the St. Marys River (Lake George Channel) and has a design treatment capacity of 54.55 X 1000 m^3 per day. The Certificate of Approval (CofA) for this facility requires 30% removal of BOD5 and 50% removal of total suspended solids (TSS). There was no criterion for total phosphorous (TP) prior to April 1989; since then it is 1 mg/L. The plant is currently undergoing further expansion with additional adjustments required for the new chemical treatment process which is not operating at design efficiency. This facility receives the effluent from a combination of residential, commercial and small industrial users.

During 1988, the Sault Ste Marie (East End) WPCP was in compliance for TSS and BOD5. On an annual average basis, 61% of the BOD5 and 77% of the TSS were removed. The average annual concentration of TP was 3.3 mg/L. The maximum average monthly concentration of TP in the effluent was 6.9 mg/L which occurred in February. Average daily flows did not exceed the plant capacity (54.55×10^3 m^3) in any month during 1988.

During 1989, the Sault Ste Marie (East End) WPCP was again in compliance for TSS and BOD5. On an average basis, 64% of the BOD5 and 78% of the suspended solids were removed. The average annual concentration of TP was 1.79 mg/L during 1989. A phosphorus treatment facility became operational in April 1989. The average TP concentration between April and December 1989 was 1.46 mg/L which was less than the annual average concentration. However, the TP criterion of 1 mg/L was not met during any month in 1989. Average daily flows exceeded the plant's capacity only in the month of April (OMOE 1990a). Sewage exceeding the plants capacity is chlorinated before discharge.

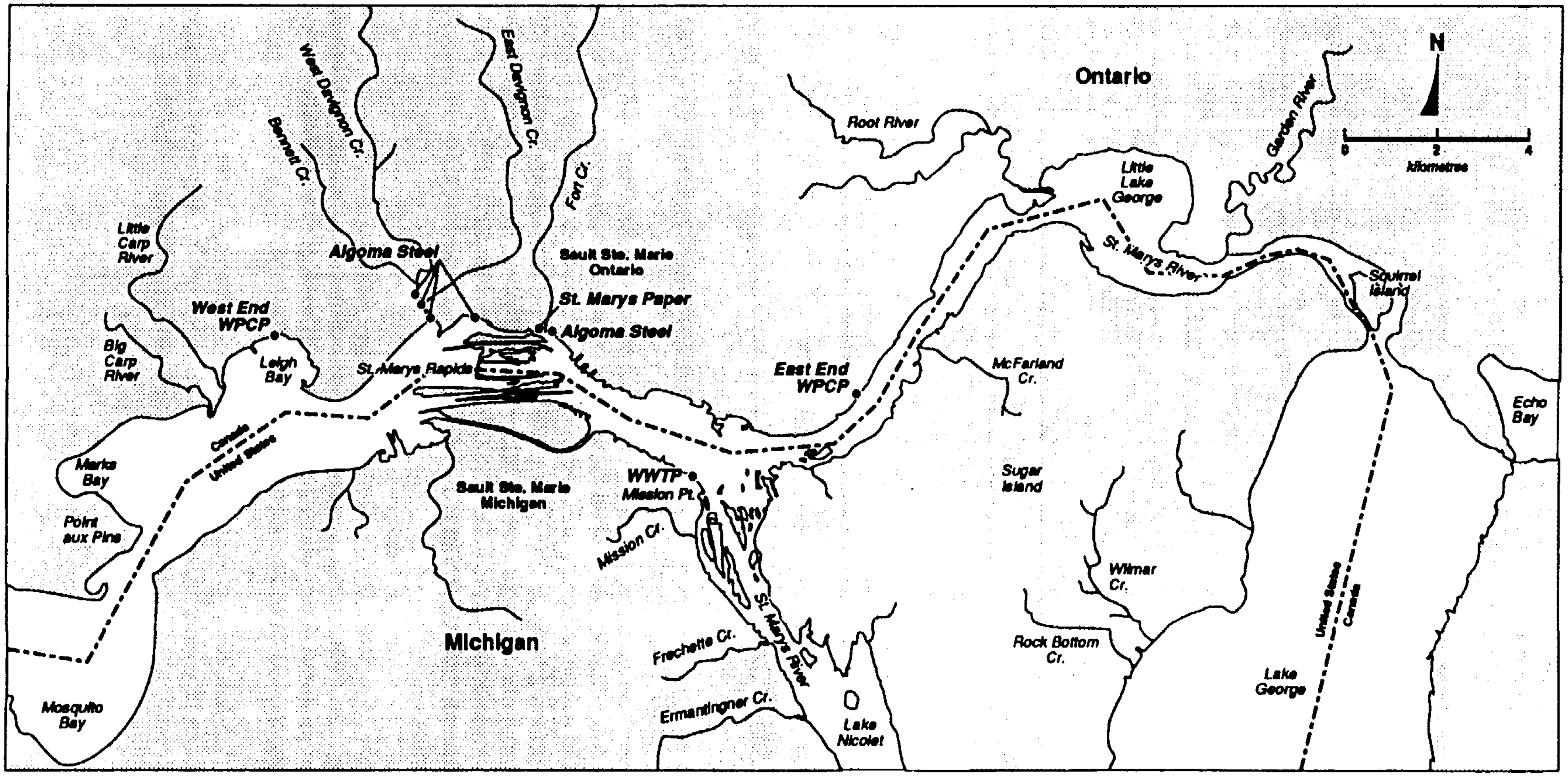
Table 8.1 shows the average annual loadings of BOD5, suspended solids and total phosphorus as well as the average annual flows for both the East End and West End WPCPs for the period 1984 through 1989.

During high flow periods, the hydraulic capacity of the plant may be exceeded resulting in the bypass of untreated sewage directly to the river. There were no bypass occurrences reported for the East End WPCP during either 1987 or 1988 (OMOE 1988, 1989a).

Figure 8.1

St. Marys River Remedial Action Plan

Location of industrial and municipal point sources on the St. Marys River



• point source discharge location

Table 8.1 Average annual 1984 through 1989* loadings of BOD_5, suspended solids and total phosphorus and flow volume for the two Ontario WPCP's which discharge to the St. Marys River AoC (OMOE 1985, 1986, 1987, 1988, 1989a and 1990a).

Facility	Year	BOD_5 (kg/d)	Suspended Solids (kg/d)	Total Phosphorus (kg/d)	Flow (m^3/day)
Sault Ste. Marie (East End) WPCP	1984	3814.04	2831.84	211.13	45,897
	1985	4183.21	3011.71	212.68	50,279
	1986	2918.67	1732.83	204.60	41,755
	1987	2106.98	1238.13	108.09	32,024
	1988	1970.50	1450.50	112.89	34,210
	1989	1555.18	1361.76	53.99	32,890
West End WPCP	1986	110.18	89.24	9.38	9,106
	1987	76.93	57.37	5.45	6,653
	1988	76.13	47.68	5.38	7,690
	1989	127.71	113.03	5.46	7,900

* West End WPCP started-up in March 1986
NA Data not available

Figures 8.2 through 8.4 show historical loading trends at the Sault Ste. Marie (East End) WPCP for BOD5, suspended solids and total phosphorous, respectively. Figure 8.5 shows the average daily flows from 1984 through 1988. The historical data show increasing BOD5 and TP from 1968 to 1983 (Figures 8.2 and 8.4). These increases were probably due to overloading the system because of population growth (UGLCCS 1988). More recent loadings of BOD5, total phosphorus and suspended solids show a marked decline beginning in 1986 and continuing through 1989 (Figures 8.2 to 8.4). These reduced loadings are paralleled by lower average flows during the same period (Figure 8.5). However, the percentage decline in loadings of all three parameters is much greater than for the flow (compare Figures 8.2 - 8.4 to Figure 8.5). Flow and total loadings decreased in 1986 (Table 8.1). Sewers servicing the western part of Sault Ste. Marie were diverted to the new plant.

The trend for TP is particularly interesting with large reductions occurring in 1987 relative to previous years (Figure 8.3). The 1989 loading of phosphorus was the lowest on record, even though the concentration criterion was exceeded during each month. The 1989 loadings of phosphorus were approximately one-third those of 1973 and less than one-half those of 1988 (Figure 8.4).

From Table 8.1 it is also apparent that the reduction in loadings at the East End WPCP was not compensated by increased loadings from the West End WPCP. The total loadings from the two facilities between 1986 to 1989 still represent a large reduction from those of only the East End WPCP prior to 1986.

Figure 8.2

St. Marys River Remedial Action Plan

Annual average BOD_5 loadings (kg/day) from 1968 through 1989 at the East End WPCP, Sault Ste. Marie, Ontario

(1968-1983 data from UGLCCS 1988; 1984-1989 data from OMOE 1985, 1986, 1987, 1988, 1989a and 1990a)

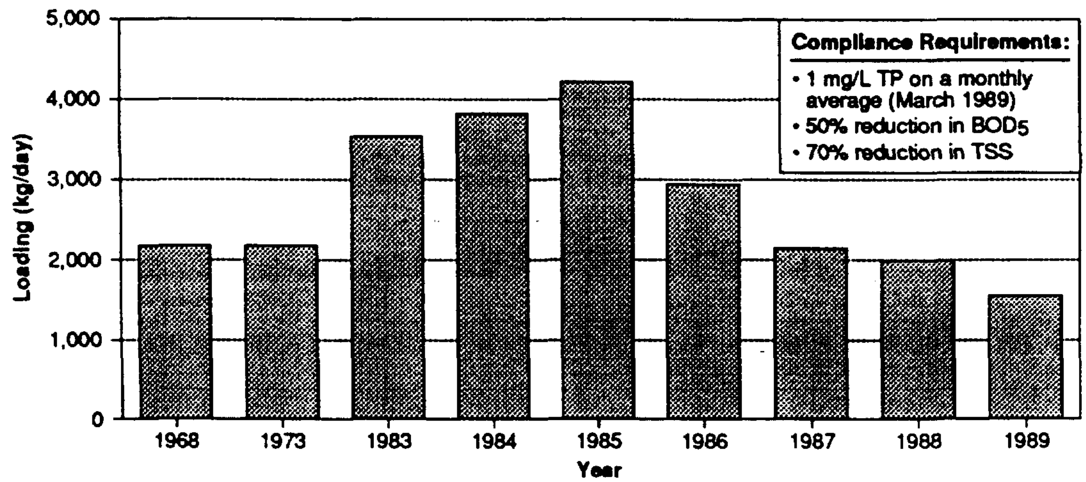


Figure 8.3

St. Marys River Remedial Action Plan

Annual average total suspended solids (TSS) loadings (kg/day) from 1984 through 1989 at the East End WPCP, Sault Ste. Marie, Ontario

(1984-1989 data from OMOE 1985, 1986, 1987, 1988, 1989a and 1990a)

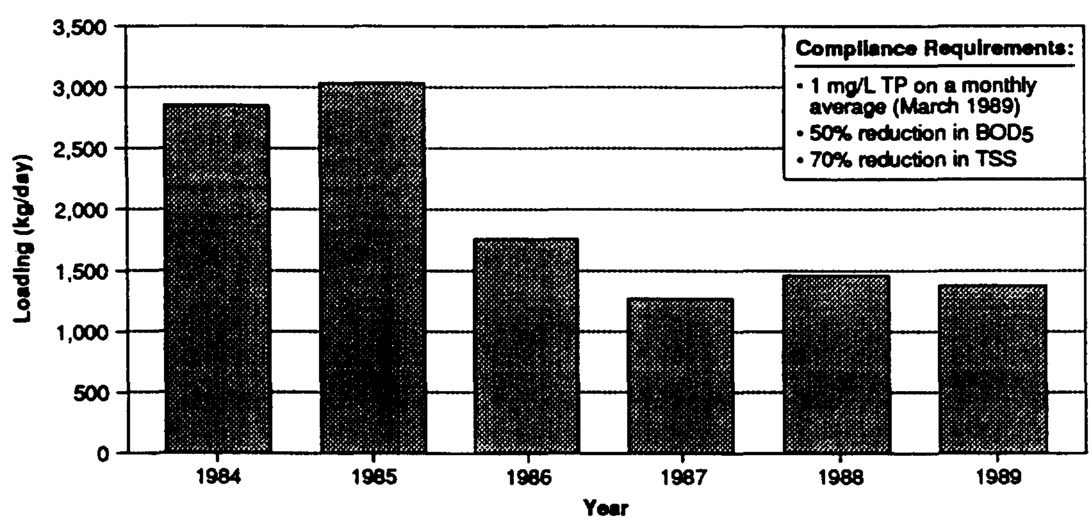


Figure 8.4

St. Marys River Remedial Action Plan

Annual average total phosphorus (TP) loadings (kg/day) from 1973 through 1989 at the East End WPCP, Sault Ste. Marie, Ontario

(1973-1983 data from UGLCCS 1988; 1984-1989 data from OMOE 1985, 1986, 1987, 1988, 1989a and 1990a)

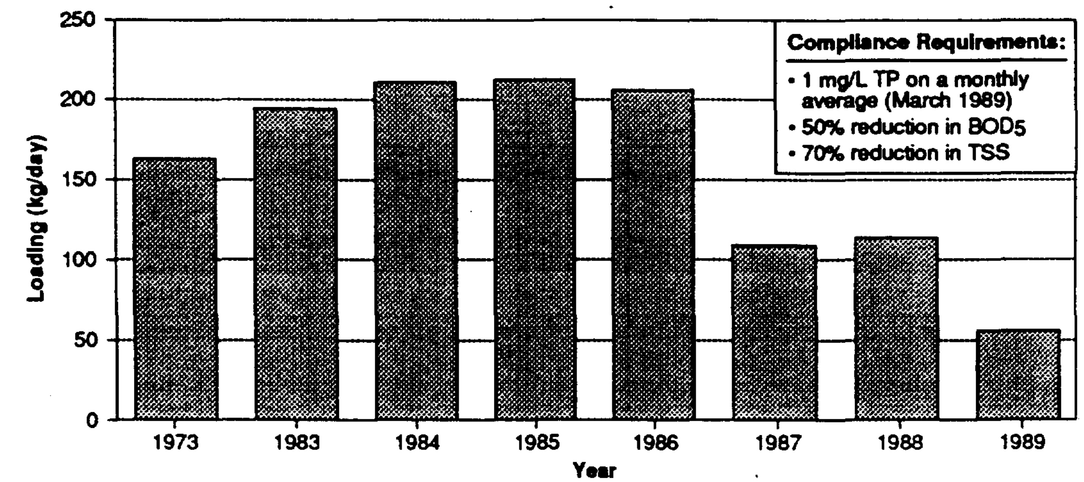
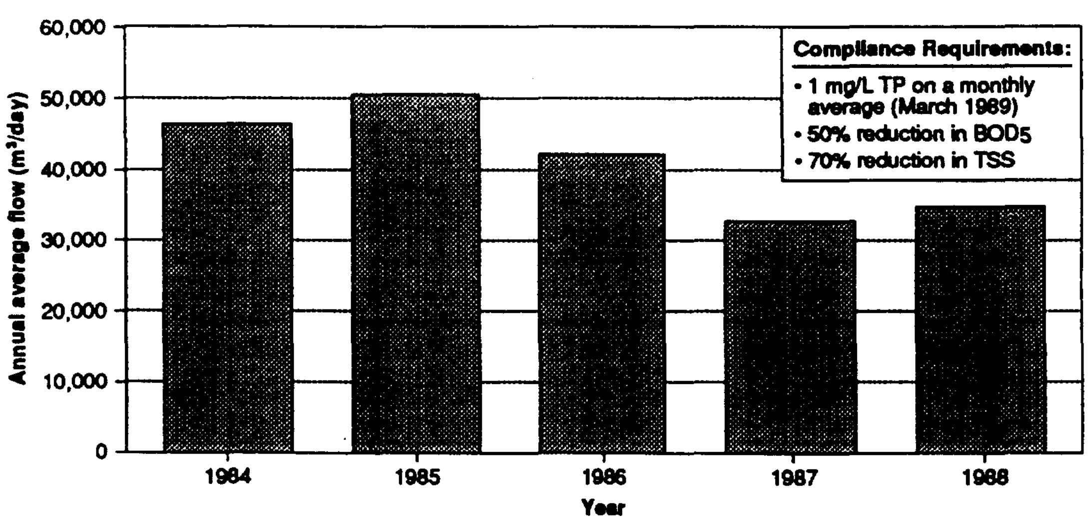


Figure 8.5

St. Marys River Remedial Action Plan

Annual average flow (m^3/day) from 1984 through 1988 at the East End WPCP, Sault Ste. Marie, Ontario

(1984-1988 data from OMOE 1985, 1986, 1987, 1988 and 1989a)



The West End WPCP is a secondary treatment facility (conventional activated sludge) with continuous phosphorus removal. It discharges directly to the St. Marys River (Leigh Bay) and has a design treatment capacity of 18.18 X 1000 m^3 per day. The CofA for this facility requires final effluent concentrations of 25 mg/L for both BOD5 and TSS and 1.0 mg/L for TP. There are no remedial measures currently under way or planned for this plant. The West End WPCP primarily services residential users.

During 1988, the West End WPCP was in compliance for all three parameters in all months. The annual average effluent concentrations were 9.9 mg/L, 6.2 mg/L and 0.7 mg/L for BOD_5, suspended solids and TP, respectively. The design treatment capacity was not exceeded in 1988 based on the daily flow averaged on a monthly basis (OMOE 1989a).

In 1989, the West End WPCP average annual effluent concentrations were in compliance for BOD5, TSS and TP. The annual average effluent concentrations were 15.8 mg/L, BOD5; 14.4 mg/L, TSS; and 0.7 mg/L, TP. However, monthly criteria were exceeded in March and especially September when BOD5 and TSS were double (51.5 mg/L BOD5 and 51. mg/L TSS) their respective criteria. TP exceeded the criterion only in the month of September 1989. The design treatment capacity was not exceeded in 1989 based on the daily flow averaged on a monthly basis (OMOE 1990a).

Although all effluent criteria have been met for 1988 and all but two months during 1989 at the West End WPCP, monthly average concentrations of BOD5 and TSS have nearly doubled from 1988 to 1989. This is also shown in the annual average loadings of both parameters, which increased by 68 and 137 percent, respectively (Table 8.1). The 1989 increases reversed an overall decreasing trend in the average annual total loadings which occurred from the opening of the plant in 1986 until 1988 (Table 8.1). Loading of BOD5 and TSS in increased in 1989 due to equipment failures and plant upsets in March and September 1989. These problems have since been resolved (LaHaye, OMOE 1990). The total phosphorus loading increased by only 1.5 percent during the same period. Average annual loadings of TP have remained virtually unchanged over the last three years of record (Table 8.1).

A total of 3,800 m^3 of sewage bypassed the Sault Ste. Marie (East End) facility during November 5 and 6, 1988. There were no bypasses in 1989 (George Adams, East End WPCP, pers. com., December 1990).

Data for 1986 reported by UGLCCS (1988) identified the Sault Ste. Marie (East End) WPCP facility as having the highest loadings of all point sources to the St. Marys River for 17 PAHs (0.417 kg/d), total phosphorus (90 kg/d), mono- and dichloramine (2.64 kg/d), chlorinated benzenes - chloroethers (0.341 kg/d); and the second highest loadings of oil and grease, (350 kg/d), ammonia (196 kg/d), chloride (2,011 kg/d), total metals (47 kg/d), volatiles (1.06 kg/d) and chlorinated phenols (1.31 kg/d). Other point sources of these contaminants include Algoma Steel, St. Marys Paper, The West End WPCP, and East Davignon, Fort and Bennett Creeks. These loadings are summarized along with those for the direct and indirect (via tributaries) industrial point sources in Section 8.2.2.

The high loading of PAHs was not considered representative of effluent quality from the Sault Ste. Marie (East End) WPCP by the UGLCCS Point Source Workgroup (1988). The Workgroup noted that this average was skewed by high results which was attributed to an industrial spill to the sanitary sewer system on the first day of sampling. On the remaining 5 days of the survey, these compounds were not found, indicating that, under normal conditions, PAHs would likely not be present at a detection limit of 1.0 $\mu g/L$ in the plant's effluent.

8.2.1.2 Michigan

The Sault Ste. Marie, Michigan Wastewater Treatment Plant (WWTP) is a secondary treatment facility with phosphorus removal and serves a population of 15,000. The facility was upgraded to secondary treatment in 1988 and the current design flow and average daily flow are 8.0 and 3.34 million gallons per day (MGD) (30.28×10^3 and 12.64×10^3 m^3/day), respectively. Treatment includes grit removal, primary clarification, biological treatment via rotating biological contractors, final clarification, chemical precipitation of phosphorus, and disinfection with chlorine prior to discharge to the St. Marys River.

Waste characterization studies and monthly discharge monitoring reports (DMRs) are used by the Michigan Department of Natural Resources (MDNR) to determine compliance with National Pollutant Discharge Elimination System (NPDES) permit limits and monitoring requirements. Effluent limitations and monitoring requirements specified by the current permit are listed in Table 8.2. All definitions and permit requirements are presented in Appendix 8.1.

No contaminants monitoring of this facility was conducted during the 1986 UGLCCS study. However, Compliance Survey Inspections (CSIs) are conducted periodically, by MDNR, at the WWTP and sampling results are compared to the required effluent limits. In the most recent CSI conducted on June 14, 1989, the results of the sample analysis were comparable to the WWTP's self monitoring data. These twenty-four hour composite samples and grab samples were also analyzed for cyanide and a number of heavy metals and organic compounds. Only two organic compounds and less than half of the heavy metals were at concentrations above the level of detection (Table 8.3). Concentrations of all parameters detected were compared to criteria developed to protect human health and prevent impacts to aquatic life. All parameters detected were below appropriate criteria (MDNR, Data Files). A brief description of sampling methods and a list of parameters analyzed are presented in Appendix 8.2.

A routine biomonitoring inspection of the Sault Ste. Marie WWTP was conducted by MDNR staff in September, 1988. A *Daphnia magna* static acute toxicity test was used to determine whether the effluent was satisfying aquatic toxicity related requirements. Results of the 1988 toxicity testing showed that the effluent was acutely toxic to *D. magna*. In test concentrations of 13% effluent and above, 100% immobilization occurred after only six hours and copper was cited as the probable cause of this toxicity (McMahon 1988). Chemical analysis of the effluent showed that copper was present in the effluent above a level predicted to be acutely toxic to aquatic life. A follow-up test was conducted in June of 1989. This test showed that the effluent was not acutely toxic to *D. magna* during the 48-hour exposure period (Dimond 1989). Copper concentrations in the effluent were reduced from 1,150 $\mu g/L$ in 1988 to 56 $\mu g/L$ in 1989 and this reduction was most likely the cause of the reduced toxicity. Monitoring requirements and permit limits for copper were added to the current permit. Beginning January 1, 1991, the final effluent limit for copper is 61 $\mu g/L$.

Total loads to the St. Marys River from the Sault Ste. Marie WWTP are shown in Figures 8.6 through 8.9. Flows from the WWTP are presented in Figure 8.10. Loads of conventional pollutants decreased substantially after the facility was upgraded in 1986, while flows have remained the same or increased slightly since 1986. The 1989 average loadings of BOD5, TSS and TP are in approximately the same range as for the West End WPCP on the Ontario side of the river.

Effluent from The WWTP was usually within requirements of the NPDES permit. However, minimum pH exceedences occurred three times in 1989 and three times in 1990. Silver concentrations exceeded the permit limit of 2.0 $\mu g/L$ once in 1989 and once in 1990. In response, the WWTP was required to develop and implement a silver minimization plan to reduce concentrations of silver in the final effluent.

8.2.2 Industrial Point Sources

Two major industries, Algoma Steel and St. Marys Paper, directly discharge to the St. Marys River.

Algoma Steel

Algoma Steel produces iron and steel from coal (coke), limestone, iron concentrates/pellets and scrap by the use of coke ovens, blast furnaces, steelmaking furnaces and rolling mills.

Table 8.2 Discharge limitations and monitoring requirements (1990) for the Sault Ste. Marie, Michigan WWTP (MI0024058) (MDNR 1990).

Effluent Characteristic	Dates in Effect	Daily Minimum	Daily Maximum	30-Day Average	7-Day Average
Flow (in MGD)	All Year	--	--	--	--
Carbonaceous Biochemical Oxygen Demand (CBOD5)	All Year	--	--	25 mg/L 756.6 kg/d	40 mg/L 1210 kg/d
Total Suspended Solids	All Year	--	--	30 mg/L 907.6 kg/d	45 mg/L 1362 kg/d
Total Phosphorus (as P)	All Year	--	--	1 mg/L	--
Dissolved Oxygen	All Year	--	--	--	--
Fecal Coliform Bacteria	5/1-10/31	--	--	200/100ml	400/100ml
Total Residual Chlorine	All Year	Monitoring Only		--	--
	All Year Beginning 1/1/91	--	0.036 mg/L		
pH (standard units)	All Year	6.5	9.0		
Copper	All Year	--	Monitoring Only		--
	All Year Beginning 1/1/91	--	61 μg/L	--	--
Silver	All Year	--	2.0 μg/L	--	--
Zinc	All Year	--	Monitoring Only		--
	All Year Beginning 1/1/91	--	397 μg/L	--	--
Cadmium	All Year	--	Monitoring Only		--
Lead	All Year	--	Monitoring Only		--

Algoma's process wastewater contains suspended solids (coal, tar, iron) and coal tar compounds (ammonia, cyanide, oil and grease and phenols) and is discharged after treatment through 6 continuous outfalls to the St. Marys River. Direct discharges to the St. Marys River from Algoma Steel include the Terminal Basins, the Bar and Strip Lagoon, the 60" Blast Furnace cooling water sewer and the 30" Blast Furnace cooling water sewer. The latter two discharge into the Algoma Slip which forms a small man-made embayment in the river. The Algoma Steel Tube Mill and Cold Mill each discharge indirectly to the river via East Davignon Creek (see Section 8.2.3). Effluent treatment consists of clarifiers, settling basins, brill skimmers, ammonia recovery stills and filtration treatment processes.

An amending Control Order was served on September 23, 1988, which required Algoma Steel to reduce waste water effluent parameters at the terminal basins outfall in accordance to the following abatement schedule and limits:

1. Ammonia and cyanide limited in combination based on toxicity considerations by February 15, 1989.

2. Limit solvent extractables to 1589 kg/day by June 30, 1989.

Table 8.3 Sault Ste. Marie, Michigan, WWTP June 14, 1989 compliance survey inspection results for metals, cyanide and detectable organic compounds (MDNR 1990).

Parameter	Sample Type	Influent µg/L	Effluent µg/L
Total Cadmium	composite	0.8	<0.2
Total Chromium	composite	4.2	<3
Total Copper	composite	100	56
Total Lead	composite	14	2.4
Total Nickel	composite	<4	<4
Total Zinc	composite	79	38
Total Iron	composite	1,800	270
Total Aluminum	composite	1,000	70
Total Mercury	composite	<0.5	<0.5
Total Selenium	composite	<1	<1
Total Arsenic	composite	1	<1
Total Silver	composite	5.9	<0.5
Hexavelant Chromium	composite	<5	<5
Total Cyanide	composite		<5
δ-BHC (lindane)	composite		0.017
1,2,4-Trichlorobenzene	composite		0.096

3. Limit suspended solids to 7355 kg/day by June 30, 1989.

4. Limit phenolics to 22.7 kg/day by June 30, 1989.

5. Install and operate a filtration plant by March 31, 1990 to limit solvent extractables to 1023 kg/day, and suspended solids to 5108 kg/day.

Algoma Steel complied with the Control Order and constructed a filtration plant with the following specifications:

- One 21.3 metre diameter primary sedimentation basin with a total volume of 2026 cubic meters and a total effective surface area of 358 square metres, including solids removal facilities and oil skimmer;
- Six horizontal centrifuged primary pumps, two rated at 852 litres per second;
- Twenty mono-media deep bed sand filters;
- Backwash system;
- Belt press filters with pre-dewatering drums;
- Instrumentation including electrical equipment and controls, waste oil storage and pumping facilities, belt filter cake storage and associated equipment;
- Maximum flow capacity of 340,690 m^3/day; and

Figure 8.6

St. Marys River Remedial Action Plan

Carbonaceous biological oxygen demand (CBOD-5 day) loadings (kg/day) to the St. Marys River from the Sault Ste. Marie Wastewater Treatment Plant, Michigan from 1980 through 1989

Data for 1983 could not be obtained

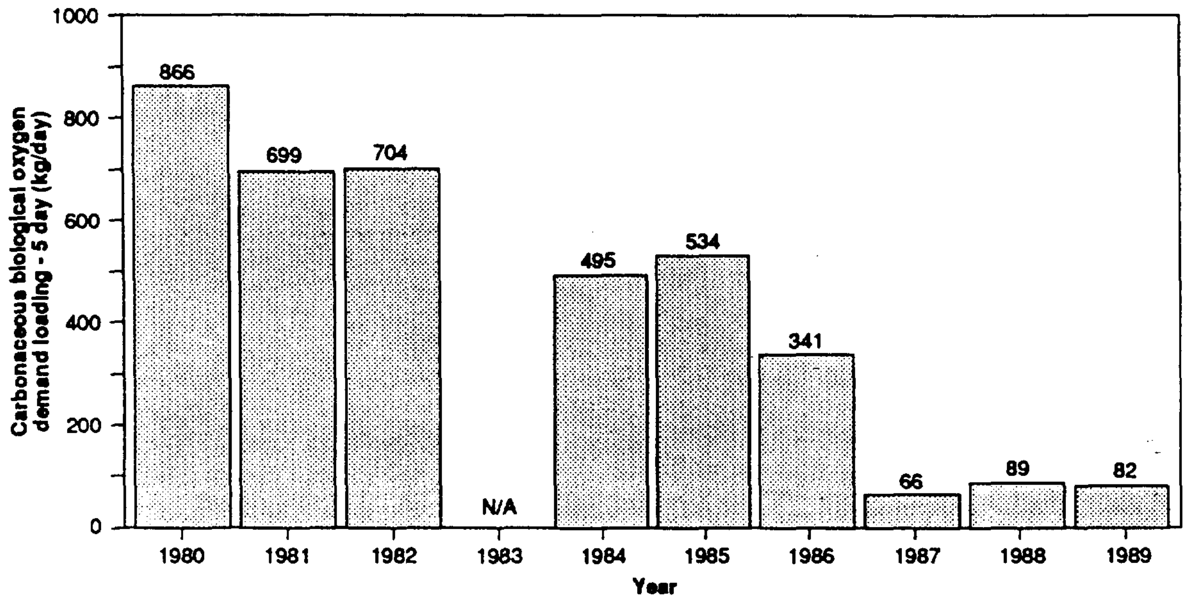


Figure 8.7

St. Marys River Remedial Action Plan

Total suspended solids (TSS) loadings (kg/day) to the St. Marys River from the Sault Ste. Marie, Michigan Wastewater Treatment Plant from 1980 through 1989

Data for 1983 could not be obtained

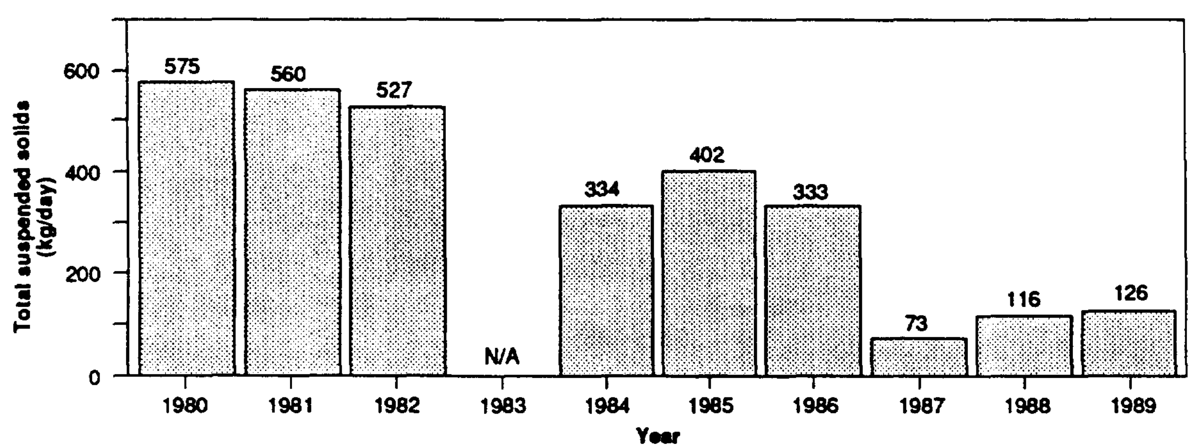


Figure 8.8

St. Marys River Remedial Action Plan

Total phosphorus (TP) loadings (kg/day) to the St. Marys River from the Sault Ste. Marie Wastewater Treatment Plant, Michigan from 1980 through 1989

Data for 1983 could not be obtained

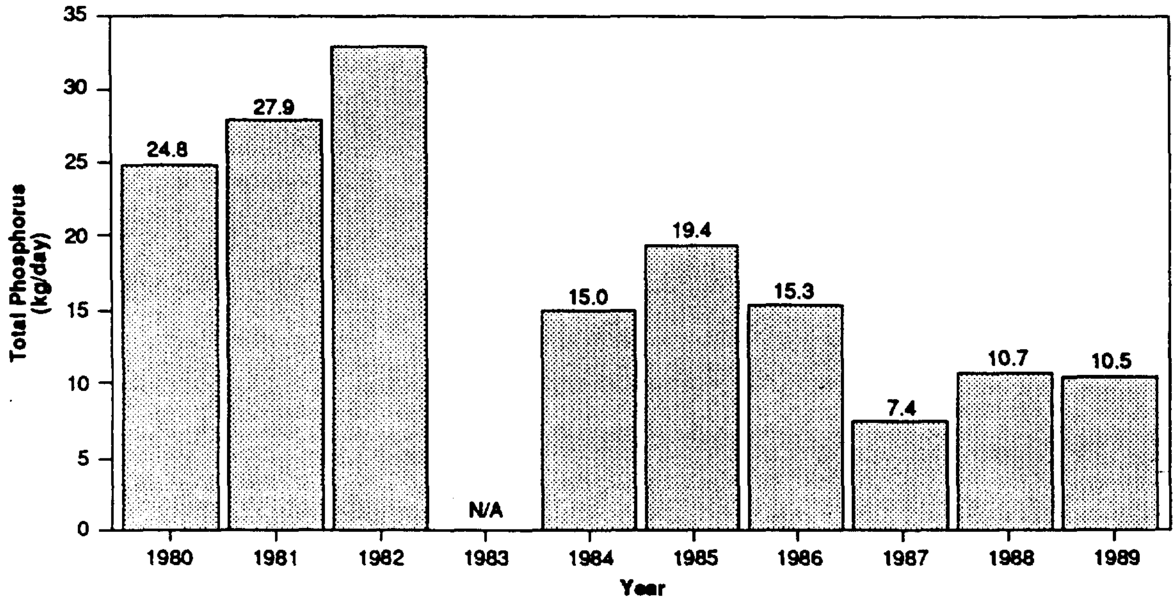


Figure 8.9

St. Marys River Remedial Action Plan

Lead, copper, zinc and silver loadings (kg/day) during 1989 to the St. Marys River from the Sault Ste. Marie Wastewater Treatment Plant, Michigan

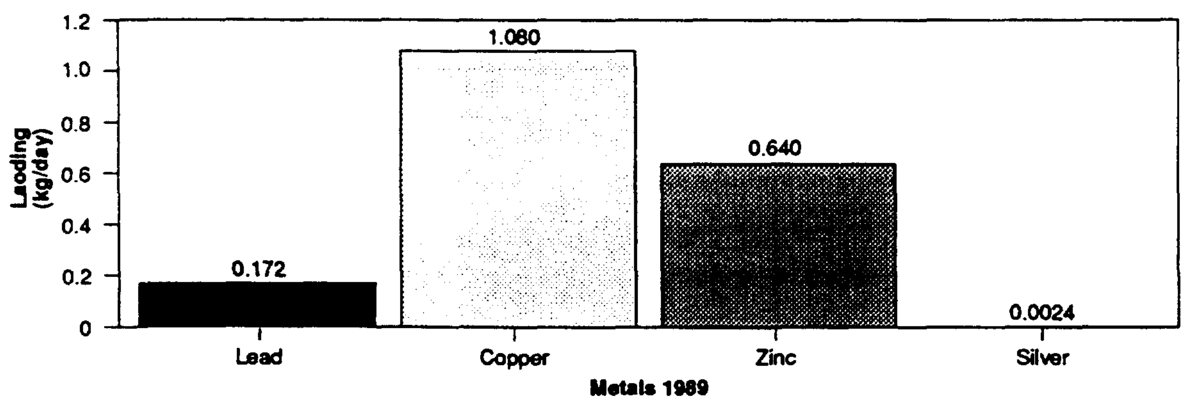
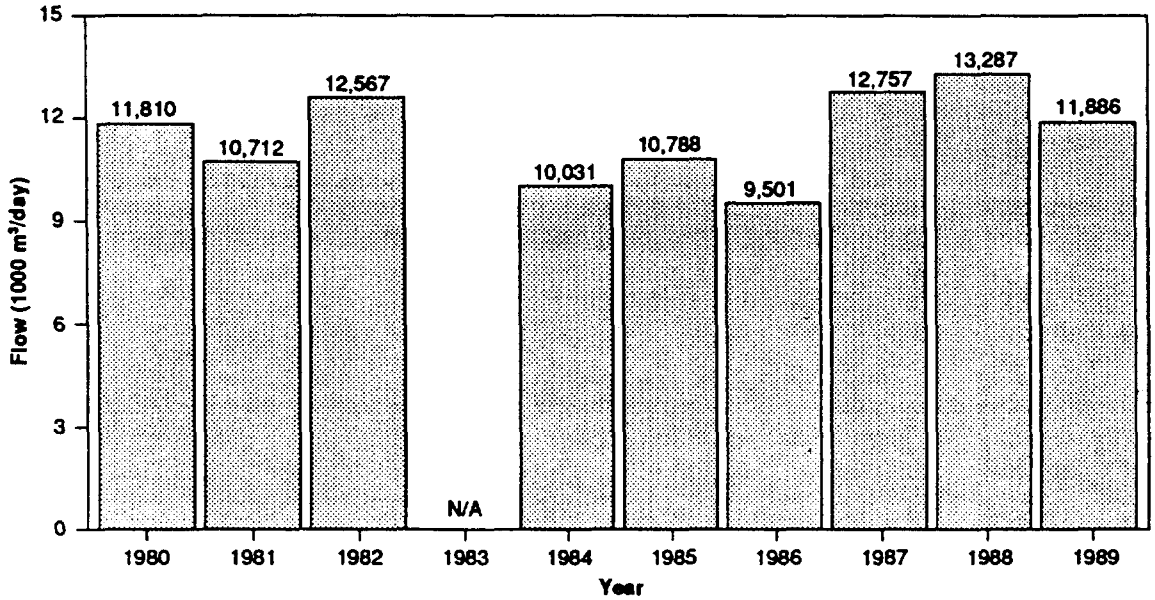


Figure 8.10

St. Marys River Remedial Action Plan

Flow (m^3/day) to the St. Marys River from the Sault Ste. Marie Wastewater Treatment Plant, Michigan from 1980 through 1989

Data for 1983 could not be obtained



- Design criteria for a wastewater flow from the Coke Oven By-Products Plant of 47.3 m^3/hour (at a 4,200 tons/day production capacity), a COD concentration of 4,120 mg/L, a phenol concentration of 680 mg/L, a cyanide concentration of 5 mg/L, and a total ammonia concentration of 1,300 mg/L.

It should also be noted that Algoma Steel also constructed a secondary (biological) treatment facility however, due to financial constraints, the plant was not commissioned.

The filtration plant was commissioned by March 31, 1990 and Algoma's effluent has been well below all Control Order effluent limits. The only data available from OMOE in Sault Ste. Marie are average loading

for total suspended solids and oil and grease for the month of August 1991. Average TSS and oil and grease loadings were 407 kg/day and 70 kg/day respectively. These loadings were well below the Control Order limits of 5,108 kg/day for TSS and 1,023 kg/day for oil and grease.

Of historical note, Algoma Steel operated at chromium smelter which was closed in 1952. The smelter was located near and discharged to the Terminal Basins outfall and may have been a source of chromium to the river.

St. Marys Paper

St. Marys Paper has one direct outfall which discharges clarifier effluent and cooling water via a multiport diffuser to the tailrace of the Great Lakes Power Corporation (UGLCCS Point Source Workgroup 1988, see Figure 8.1 for locations).

St. Marys Paper, by adding purchased kraft pulp to pulp produced by the stone groundwood process, produces paper specialties used in newsprint. Clay lime was added in December of 1984 and a slush pulp multi-product mill (with no white water discharge) was constructed in 1989. There is no bleaching (chlorine), which is typical of most kraft pulp mills, used in the process.

St. Marys process wastewater contains suspended solids (bark, clay, wood) and soluble organic compounds like sugar. The average effluent flow to the St. Marys River was 34,828 m^3/day in 1990.

Effluent levels have been established and regulated by a Certificate of Approval based on the 1971 Federal "Pulp and Paper Mill Regulations". These regulations require St. Marys Paper to operate its mill so that the discharge of total suspended solids in the "clear water sewer" effluent, averaged over any 30 consecutive working days, will not exceed the allowable load levels calculated from production/furnish mix formula. At no time is the maximum daily limit of suspended solids to exceed twice the average load level referred to above.

Effluent treatment consists of a bull screen and clarifier with a scum collector on the overflow. An internal recovery system removes excess clays. Discharge is continuous through a submerged diffuser. Total suspended solids in St. Marys Paper effluent have been in compliance for the entire year of 1990.

Loadings

The 1986/87 loadings for 23 parameters reported in the UGLCCS (1988) final report for each of the direct and indirect industrial point sources to the St. Marys River are provided in Table 8.4. The 1987 loadings by outfall for Algoma Steel and for St. Marys Paper are provided in Table 8.5 for nine parameters.

Most of the data in Table 8.4 represent average daily loadings based on analyses of samples collected by Environment Canada and the Ontario Ministry of the Environment in a 3 to 6 day survey during August 1986

Table 8.4 Loading summary of Ontario and Michigan point source discharges for 1986 (1989 for Michigan WWTP) to the St. Marys River (kg/d) based on point source surveys, self monitoring data and OMOE pilot site investigations (data from UGLCCS (1988) except where footnoted). Michigan WWTP is from 1989 CSI and 1990 self monitoring data.

Parameter	Algoma Steel	St. Marys Paper	East End WPCP	West End WPCP	Michigan WWTP (1989)	E. Davignon Creek	Fort Creek	Bennett Creek	Total Loadings to St. Marys River
Flow (m^3/d)	486,375	23,710	30,638	8,753	7,972	87,048	3,145	3,145	650,786
Oil and Grease	9,490 (1950)* (3547)‡	231	349.7	13.3	84	NA	NA	NA	10,035 (2544) (4141)
Ammonia	6,254 (3990)†	6.01	195.5	14.8	29	17.6	0.172	2.8	6,481 (4227)
Total Phosphorus	20.0	4.70	89.8	5.7	10.5§	2.7	0.41	0.066	129.6
Suspended Solids	4,234† (8137)†	2,829	900.6	39.4	126§	1,713	353	158	10,274 (15300)
Chloride	18,885	743	2011.1	598.5	640	952.6	286	671	24,137
Cyanide	72.9	NA	NA	NA	0.060	0.294	0.0031	0.022	73.2
Total Phenols	9.0 (96.5)† (114)‡	0.708	0.512	0.022	NA	0.61	0.0041	0.075	11 (116)
Copper	-1.1	0.328	1.4	0.2	1.08§	NA	NA	NA	0.83
Iron	1,747 (2275)‡	8.65	42.6	5.2	3.2	71.8	12.2	1.22	1,889 (2417)
Lead	4.81	0.168	1.01	0.187	0.17§	NA	NA	NA	6.18
Mercury	0.005	0	0.0005	0.0001	ND	NA	NA	NA	0.0056
Zinc	33.7	0.09	1.91	0.356	0.64§	0.761	0.127	0.054	37.3
Xylene	0.388	0.05	0.223	ND	ND	ND	ND	NA	0.66
Styrene	0.084	ND	NA	ND	NA	NA	NA	NA	0.084

Table 8.4 (Cont'd)

Parameter	Algoma Steel	St. Marys Paper	East End WPCP	West End WPCP	Michigan WWTP (1989)	E. Davignon Creek	Fort Creek	Bennett Creek	Total Loadings to St. Marys River
Benzene	0.14	0	0.048	0.011	ND	ND	ND	NA	1.18
Chloroform	0.004	0.066	0.079	0.031	ND	ND	ND	NA	0.18
Methylene Chloride	0.124	0.0088	0.233	0.030	ND	NA	NA	NA	0.4
Toluene	0.231	0.168	0.158	0.005	ND	ND	ND	NA	0.56
2,4,6-Trichlorophenol	1.48	0	0.004	0.037	ND	NA	NA	NA	1.52
2,4-Dimethylphenol	1.21	-0.06	0.727	0.075	ND	NA	NA	NA	1.95
Total PAHs (16)	0.20 (1.21)	0.051	0.417	0.004	ND	0.04	0.006	0.005	0.72 (1.73)
1,4-Dichlorobenzene	0.125	0.030	0.043	0.010	ND	ND	ND	NA	0.21
Mono & Dichloramine	NA	NA	2.64	0.600	NA	NA	NA	NA	3.24

NA - Not Analyzed, ND - Not Detected
* 1986 self-monitoring data (net).
† Loadings for Terminal Basins from average for the self-monitoring program for 1986 substituted into database as August loadings for those parameters considered atypical.
‡ Represents data of OMOE Pilot Site investigation (gross).
§ 1989 self monitoring data

(UGLCCS 1988). "Loadings of individual contaminants were calculated by multiplying the flow rate at the time of sampling by the gross or net concentration of the contaminant and a conversion factor. Gross concentrations were used for the Municipal WPCPs and net concentrations are reported for the industrial sources. If the net concentration for a given day was negative, a negative net loading was reported" (UGLCCS Point Source Workgroup 1988). Loading estimates from the August 1986 UGLCCS survey were compared to gross estimates based on two long-term surveys; the OMOE MISA pilot site study (May to November 1986) and the effluent self-monitoring program (January to December 1986). This comparison revealed that loadings of phenols, total PAHs, ammonia, suspended solids and oil and grease from Algoma Steel are both positively and negatively variable and that the UGLCCS data for some parameters are probably not representative of the operational conditions of treatment facilities. Therefore, average gross loadings calculated from the self-monitoring or MISA pilot site data were included in Table 8.4.

Table 8.5 shows the mean and range of concentrations for nine parameters at each of Algoma's four direct discharges to the river. The data were collected in 1987 and 1988 as part of the MISA pilot site investigation and were used to calculate some of the total facility loads in Table 8.4. Loadings contributed by each of the four outfalls are not available. The data illustrate the marked variability in concentrations of contaminants in effluents over a one year period. This is further illustrated by comparison of the total phosphorus and suspended solids loadings reported for the two Ontario WPCPs during the UGLCCS 3 to 6 day survey versus the annual averages. For example, for the East End WPCP, total phosphorus loads in 1986 were reported as 89.8 kg/d by UGLCCS (Table 8.4) and as 204.6 kg/d by OMOE (Table 8.1). Similarly, suspended solids were 900.6 kg/d based on the shorter survey (UGLCCS, Table 8.4) as compared to 1732 kg/d for the annual average (Table 8.1). Loadings of these two parameters were also underestimated in UGLCCS (1988) for the West End WPCP.

The total loading of oil and grease to the St. Marys River estimated from point sources during the 1986 UGLCCS survey was approximately 10,000 kg/d. An average of 9,490 kg/d was discharged from Algoma's Terminal Basins, accounting for about 95% of the total point source discharge to the river. This also far exceeded Algoma's Control Order limit of 1,589 kg/d which was to be met by December 31, 1986. The oil and grease loading from Algoma during the UGLCCS survey was well above the average daily load as calculated from 1986 (annual) self-monitoring data (1,950 kg/d), the August 1986 self-monitoring data (1,470) and the MISA pilot site investigation data (3,547 kg/d). The reason for this variability is unknown.

The Terminal Basins and the Bar and Strip Lagoon discharges of Algoma Steel were the principle sources of ammonia during the UGLCCS 1986 survey, contributing an average of 5,960 kg/d and 210 kg/d, respectively. The average ammonia loading from Algoma Steel during this survey (6,254 kg/d) was higher than loadings based on the 1986 annual self-monitoring data which indicated an annual average of 3,990 kg/d and the August 1986 average of 2,490 kg/d.

The total suspended solids (TSS) loading to the St. Marys River during the 1986 UGLCCS survey was 8,000 kg/d. Approximately 88% of this was discharged by industrial and municipal facilities. Algoma Steel had the highest TSS loading (4,234 kg/d), of which the Terminal Basins contributed 3,950 kg/d. This load was well below the average TSS load from the Terminal Basins as estimated from the 1986 annual self-monitoring data (7,790 kg/d), and the load based on August 1986 self-monitoring data (6,640 kg/d). Based on the UGLCCS data, the Terminal Basins effluent met the Amending Control Order limits required as of March 31, 1990. However, Algoma's self-monitoring data indicate that the loads were above this limit as well as the Control Order limit which existed at the time of the survey (7,355 kg/d).

St. Marys Paper contributed an average TSS load of 2,829 kg/d, the second highest. Effluent TSS concentrations at St. Marys Paper was in compliance with their Certificate of Approval. Suspended solids loadings from the paper plant have declined steadily between 1968 (23,800 kg/d) and 1986 (2,829 kg/d) (UGLCCS 1988).

Table 8.5 Mean and range of contaminant concentrations observed in Algoma Steel and St. Marys Paper effluents during a one year period (1987) (from UGLCCS 1988).

Parameter	MDL	Algoma Steel				St. Marys Paper
		30" Blast Furnace	60" Blast Furnace	Bar & Strip Lagoon	Terminal Basins	
Oil and Grease	1.0 mg/L	3.7 (ND-40.0)	3.6 (ND-50.0)	8.3 (ND-581)	7.6 (ND-48)	18.4 (ND-720)
Ammonia	0.5 mg/L	27.17 (ND-1,060)	0.100 (ND-1.060)	1.356 (ND-5.30)	7.481 (ND-16.50)	0.078 (ND-720)
Suspended Solids	0.1 mg/L	52.19 (2.10-353)	30.48 (1.90-557)	12.85 (3.50-59.4)	26.04 (2.4-121)	190 (1.8-2150)
Cyanide	0.001 mg/L	0.028 (ND-0.590)	0.025 (ND-2.00)	0.545 (ND-2.60)	0.106 (ND-0.90)	0.004 (ND-0.02)
Total Phenols	0.2 μg/L	473 (0.4-29,000)	3.06 (0.20-28.4)	15.5 (0.40-144)	395 (1.20-8750)	20.8 (0.6-374)
Iron	0.05 mg/L	8.53 (0.55-200)	5.20 (ND-140)	1.95 (ND-43.0)	6.01 (0.36-64.0)	1.36 (0.27-15.0)
Lead	0.01 mg/L	0.038 (ND-0.59)	0.016 (ND-2.50)	0.076 (ND-0.82)	0.018 (ND-0.600)	0.030 (ND-0.830)
Mercury	0.01 μg/L	0.514 (ND-19.0)	0.016 (ND-0.230)	0.009 (ND-0.050)	0.045 (ND-0.700)	0.018 (ND-0.050)
Zinc	0.005 mg/L	0.168 (0.007-5.00)	0.039 (ND-1.00)	0.821 (0.10-13.00)	0.021 (ND-0.500)	0.063 (0.005-0.740)

ND Not Detected at method detection limit (MDL).

Data from St. Marys River MISA Pilot Study, twice-weekly grab sampling, March 2, 1987 to March 28, 1988 (approximately 100 samples).

The average total phenols loading to the St. Marys River during the August 1986 UGLCCS survey was 11 kg/d. Algoma Steel contributed 9.0 kg/d, of which 8.2 kg/d was discharged from the Terminal Basins. The Point Source Workgroup Report (UGLCCS 1988) considered the measured loading from the Terminal Basins to be quite atypical and not representative when compared (data collected over a short period of time, 3 to 6 days) with Algoma's 1986 annual self-monitoring data (95.7 kg/d). Loadings of total phenols to the St. Marys River from Algoma Steel, using Algoma's data and the MISA pilot site investigation data were 96.5 kg/d and 114 kg/d, respectively. St. Marys Paper had the second highest total phenols loading during the UGLCCS survey (0.71 kg/d). Since June 1989, phenol levels in the Terminal Basins effluent have averaged below the Control Order requirement of 22.7 kg/d due to internal changes in the by-product system (LaHaye, OMOE, 1990).

During the UGLCCS survey, 17 PAH compounds were analyzed for in the effluents. An average of 0.72 kg/d of total PAHs was discharged during the August, 1986, survey (UGLCCS Point Source Workgroup 1988). As noted in Section 8.2.1, the highest average loading of total PAHs was from the Sault Ste. Marie Ontario East End WPCP (0.417 kg/d, Table 8.4). During the August 1986 survey, an average of 0.2 kg/d total PAHs was discharged by Algoma Steel. All PAH compounds analyzed for were detected in the Algoma Steel coke plant effluent which discharges to the Terminal Basins. However, only 3 PAH compounds were detected in the Terminal Basins effluent and only at trace concentrations, close to the analytical detection limits. As with other loading data presented, there is substantial variability in calculated PAH loadings from Algoma Steel. Based on the 1986 MISA pilot site data, an average of 1.14 kg/d total PAHs was discharged from the Terminal Basins alone. However, this PAH loading is not representative of current levels (OMOE unpublished data; LaHaye, OMOE, pers. comm.).

Comparison of the point source loadings generated by the UGLCCS survey (Table 8.4) indicates that Algoma Steel had the highest loading of oil and grease (9,490 kg/d), ammonia (6,254 kg/d), suspended solids (4,234 kg/d), chloride (18,885 kg/d), cyanide (72.9 kg/d), total phenols (9.0 kg/d), total metals (1,784.4 kg/d), total volatiles (1.95 kg/d) and chlorinated phenols (2.39 kg/d).

In the Algoma complex, the Terminal Basins outfall is the major source of pollutants, followed by the Bar and Strip Lagoon for lead, zinc and cyanide (Table 8.5). The Terminal Basins effluent comprises about 80% of Algoma Steel's effluent flow. Yearly trends in the effluent quality of the Terminal Basins indicate a steady decline in ammonia, cyanide and phenol concentrations from 1976 to 1986 (UGLCCS 1988). These trends are based on data collected through Algoma's self monitoring program. The new filtration system which Algoma Steel added to the effluent stream discharging at the Terminal Basins is expected to further reduce loadings of many of the contaminants.

Table 8.6 lists the 1988 total average loadings for those parameters monitored under the Certificate of Approval for St. Marys Paper and the Control Order for Algoma Steel. Seven parameters shown in Table 8.6 can be compared to the 1986 data for Algoma and only one is comparable for St. Marys Paper (Table 8.4).

The trend of decreasing cyanide and ammonia contributed by Algoma Steel to the Terminal Basins, as noted above, appears to have continued through 1988 (Table 8.6). This is particularly significant, given that the 1988 data are for total effluent not just for the Terminal Basins. However, the loading for total phenols has increased somewhere between 1.4 and 17.8 times, depending on which loading value from 1986 is used. Algoma Steel shows an increase in phenol output from an annual average of 114 kg/d in 1986 to 160 kg/day during 1988 (Table 8.6).

Other parameters for which loadings increased in 1988 relative to 1986 include suspended solids and unfiltered iron. Slight decreases were observed for free cyanide and filtered zinc. Oil and grease and ammonia-N during 1988 were both within the lower range of the results reported for 1986/87. The criteria for suspended solids and oil and grease were regularly exceeded during 1988 (Table 8.6).
Although the loadings of oil and grease exceeded the Control Order 10 out of 12 months, a follow up investigation revealed the monitoring facilities to be inadequate. OMOE amended the control order to include the installation of satisfactory monitoring equipment.

At St. Marys Paper, flows have increased by 4,600 m^3/day and the suspended solids have nearly doubled from 1986 to 1988, reversing the decreasing trend observed between 1968 and 1986. These increases are due to the addition of a new paper machine in 1986 (LaHaye 1990).

Table 8.6 Average annual loadings in kg/day and exceedences (# of months) of parameters under the control of a Certificate of Approval or Control Order for the Sault Ste Marie, Ontario industrial facilities during 1988 (OMOE 1989b) as compared to loadings for 1986/87 (from Table 8.4).

Facility	Year	Flow (m^3/d)	Ammonia as N	Total Phenols	Suspended Solids	Oil and Grease
St. Marys Paper	1986	23,710	6.01	0.71	2,829	231
	1988	28,301	-	-	5,035 (1)	-
Algoma Steel	1986/87	486,375	3,990-6,254	9.0-114	4,234-8,137	1,950-9,441
	1988	480,065	3,806 (NA)	160 (NA)	8,591 (6)	2,475 (10)

Facility	Year	Flow (m^3/d)	Cyanide (free)	Iron (unfilt)	Zinc (filt)	Sulphate (unfilt)
St. Marys Paper	1986	23,710	-	8.6	0.09	-
	1988	28,301	-	-	-	-
Algoma Steel	1986/87	486,375	72.9	1,747-2,275	33.7	-
	1988	480,065	64.5 (NA)	2,321 (NA)	24.7 (NA)	768 (NA)

\- = not monitored
NA = not applicable

8.2.3 Tributary Sources

For purposes of this discussion, tributaries to the St. Marys River are considered as point sources to the river. Contaminants found in the tributaries are actually derived from a combination of point and non-point sources including: industrial point sources, such as Algoma's Cold Mill cooling water (24" sewer) and Tube Mill process and cooling water which enter East Davignon Creek, industrial surface runoff, such as the Algoma Steel Site and the former Domtar Plant site which drains into East Davignon, Bennett and Fort Creek; as well as runoff from rural and residential areas, as in the case for Big Carp River, Root River and Clark Creek. It is difficult to separate the various sources to each creek and, hence, for ease of data presentation, all tributary data will be considered in this section. There is no data available for the Echo and Bar Rivers.

8.2.3.1 Ontario

Table 8.7 presents contaminant loadings and concentrations for five tributaries monitored by the OMOE stream water quality network between January 1988 and February 1990 (OMOE 1990b). Loadings were calculated by multiplying mean total concentrations and mean total flow over the period of record. In general, the five Ontario tributaries do not appear to be significant sources of contaminants to the St. Marys River when compared to the other point sources. East Davignon Creek and the Root River contribute small amounts of ammonia, nitrate plus nitrite and TKN to the St. Marys River. All tributaries contain significant amounts of suspended solid material.

Table 8.7 Loadings (1988-1990), mean concentrations[1] and standard deviation for selected contaminants[2] in Canadian tributaries of the St. Marys River (OMOE 1990b). Average flow over the period of record is shown for each tributary except Clark Creek for which data were not available.

	Aluminum	Copper	Iron	Nickel	Lead	Zinc	NH_3-N	NO_2+NO_3-N	TKN	Total Phenols	Total Phosphorus	Suspended Solids	Cyanide
Big Carp River (56,506 m^3/d)													
Loading (kg/d)	20.46	0.10	48.03	0.09	0.12	0.43	3.96			0.08	1.86	2260	
Mean	362	1.7	850	1.6	2.1	7.6	0.07	NA	NA	1.5	0.033	40	NA
+/- Std dev (geom)	196	1.2	683	1.3	0	4.6	0.05			1.1	0	6	
Start period of record	01/88	04/88	01/88	01/88	01/88	04/88	02/84			02/84	02/84	02/84	
End period of record	02/90	02/90	02/90	02/90	02/90	02/90	02/90			02/90	02/90	02/90	
n	22	21	23	22	22	21	60			59	60	59	
East Davignon Creek (20,995 m^3/d)													
Loading (kg/d)	2.69	0.05	6.63	0.03	0.04	0.09	5.67	8.23	11.57	0.21	0.78	251.94	0.04
Mean	128	2.2	316	1.2	2.0	4.2	0.27	0.392	0.55	10.2	0.037	12	0.00
+/- Std dev (geom)	91	1.8	258	1.1	0	3.7	0.15	0.375	1	5.5	0.025	6	2
Start period of record	01/88	04/88	01/88	01/88	01/88	04/88	02/84	02/84	0.42	02/84	02/84	02/84	0.00
End period of record	02/90	02/90	02/90	02/90	01/90	12/89	01/90	01/90	7	03/90	01/90	01/90	1
n	20	20	22	20	20	20	57	60	02/84 01/90 59	62	60	60	02/84 11/89 38
Fort Creek (20,736 m^3/d)													
Loading (kg/d)	23.95	0.24	28.97	0.07	0.15	0.39	1.66			0.04		829.44	
Mean	1155	11.7	1397	3.6	7.3	19	0.08	NA	NA	1.8	NA	40	NA
+/- Std dev (geom)	738	4.9	1148	2.6	5.6	16.2	0.04			1.2		25	
Start period of record	01/88	04/88	01/88	04/88	04/88	04/88	02/84			02/84		02/84	
End period of record	02/90	02/90	02/90	02/90	02/90	02/90	02/90			03/90		02/90	
n	21	20	22	19	20	20	55			54		54	
Clark Creek[3]													
Loading (kg/d)	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	NA	4.9	2871	NA	9.0	31.8	NA	NA	NA	2.3	0.06	121	0.00
+/- Std dev (geom)		4	2745		0	22.5				1.1	0.045	29	1
Start period of record		04/88	04/88		05/88	04/88				05/88	05/88	05/86	0.00
End period of record		12/89	12/89		12/89	12/89				03/90	01/90	01/90	1
n		19	21		20	19				36	41	40	05/86 01/90 27

Table 8.7 (Cont'd)

	Aluminum	Copper	Iron	Nickel	Lead	Zinc	NH_3-N	NO_2+NO_3-N	TKN	Total Phenols	Total Phosphorus	Suspended Solids	Cyanide
Root River (213,667 m^3/d)													
Loading (kg/d)	66.02	0.38	125.42	0.32	0.66	2.05	21.37			0.28	4.70	3632	
Mean	309	1.8	587	1.5	3.1	9.6	0.1	NA	NA	1.3	0.022	17	NA
+/- Std dev (geom)	230	1.2	545	1.2	0	5.2	0.06			0.8	0.017	9	
Start period of record	01/88	04/88	01/88	04/88	01/88	04/88	02/84			02/84	02/84	02/84	
End period of record	02/90	02/90	02/90	02/90	02/90	02/90	02/90			02/90	02/90	02/90	
n	22	20	22	20	20	20	55			54	55	54	

1 µg/L - Al, Cu, Fe, Ni, Pb, Zn, phenols.
mg/L - NH_3-N, NO_2+NO_3-N, TKN, TP, suspended solids, cyanide.

2 Al, Cu, Fe, Ni, Pb, Zn, TP, TKN, phenols, cyanide = total unfiltered.

3 Loadings not calculated as flow data is not available.

NA = no data

Based on the 1986 loadings data presented by UGLCCS (1988) for two of these creeks (East Davignon and Fort Creeks, see Table 8.4), and the OMOE 1988-1990 data (Table 8.7) there appears to little or no change for most parameters. Results indicate decreasing loadings of cyanide (0.04 compared to 0.29 kg/d), total phenols (0.21 compared to 0.61 kg/d), total phosphorous (0.78 compared to 2.7 kg/d) and iron (6.63 compared to 71.8 kg/d) for East Davignon Creek. Fort Creek had slightly higher loadings of ammonia (1.66 vs. 0.17), TSS (829 vs. 353), total phenols (0.04 vs. 0.004) and iron (29.0 vs. 12.2) in 1988-90 than 1986.

East Davignon Creek receives effluents from Algoma Steel in addition to urban inputs, whereas the other tributaries primarily drain residential and small industrial areas. The Root River, which drains a residential area on the east side of Sault Ste. Marie, contributed the highest loadings for each parameter of the four tributaries for which loading data were calculated (Table 8.7). Of particular interest are exceedences of Provincial Water Quality Objectives (PWQO). The PWQO for total phenols (1 $\mu g/L$) and iron (300 $\mu g/L$) were exceeded by the mean concentrations in all five creeks for the period of record (Table 8.7). Fort Creek and Clark Creek had particularly high concentrations of iron. The PWQO for total phosphorous (in streams and rivers, 0.03 $\mu g/L$) was slightly exceeded in three of the creeks. The PWQO for zinc (30 $\mu g/L$) was exceeded in Clark Creek (31.8 $\mu g/L$) and for copper (5 $\mu g/L$) in Fort Creek (11.7 $\mu g/L$).

With the exception of Fort Creek, bottom sediments from the Ontario tributaries would be classified as nonpolluted (Hesselberg and Hamdy 1987).

Peripheral to the Algoma slag dump are the West Davignon Diversion Channel, Baseline Road ditch and Bennett Creek. An ongoing investigation sponsored by OMOE (Beak 1989) has determined that the West Davignon Diversion Channel and Baseline Road ditch are shallow groundwater discharge zones. Preliminary testing shows the main slag pile and disposal area appear to be a major source of groundwater contaminants. Preliminary testing was done only for phenols, sulphate, chloride and specific conductance. "Relatively undiluted source area groundwater appears to be discharging directly to the West Davignon Creek" (Beak 1989). PAHs were identified in groundwater in the vicinity of the slag pile and disposal area. Subsequent surveys by Beak Consultants Limited will quantify and determine phenol and PAH trends.

8.2.3.2 Michigan

None of the Michigan tributaries to the St. Marys River have been monitored recently for water quality. However, in 1985, the U.S. EPA collected samples of bottom sediment from 18 Michigan tributaries to evaluate their importance as sources of contaminants to the St. Marys River. The samples were analyzed for conventional pollutants, metals, pesticides, PCBs and other organic compounds. The results of this study indicate that Michigan tributaries are not a significant source of contaminants to the St. Marys River. The sediment samples contained no obvious evidence of pollution and sample analysis resulted in most sediments being classified as nonpolluted. Additional water quality sampling from the Michigan tributaries is thus required to verify this conclusion. Samples collected from streams which drain the City of Sault Ste. Marie, Michigan, where contaminant sources are most likely, were generally free of significant contaminant concentrations.

8.3 NON-POINT SOURCES

Non-point source pollutant loads are introduced into the environment from diffuse sources which enter the water system through a wide range of pathways. Furthermore, non-point pollutant loads are dependent on many natural phenomena such as rainfall, wind speed and direction, soil types and geological terrain and relief. Due to the nature of non-point source pollutant loads, assessment of their magnitude and impacts is often difficult and studies have not been done for the AoC. The source of contaminants are many and can include the atmosphere, spills, terrestrial natural sources, wastes disposal sites, and surface drainage.

8.3.1 Combined Sewer Overflows (CSOs)

8.3.1.1 Ontario

There are no CSOs serving the City of Sault Ste. Marie, Ontario. However, during periods of heavy runoff, the East End WPCP has been subjected to peak flows of up to 209 x 10^3 m^3 (design capacity is 54.5 x 10^3 m^3), due to rain water infiltration and improper cross connections between residential roof drains and weeping tile systems with the sanitary sewer system.

All sewage passing through the East End WPCP receives primary treatment, phosphorus removal and chlorination prior to discharge. During heavy runoff periods, the City pumps untreated sewage directly from the sanitary sewer system to the storm sewer system, to prevent flooding of basements in residential areas. It is unknown as to what extent sanitary sewers overflow directly to the river without treatment. An OMOE funded "Lifelines" program has been proposed to the City to study this problem.

8.3.1.2 Michigan

Approximately 85% of the sewer system for the City of Sault Ste. Marie, Michigan consists of combined stormwater and sanitary sewers (CSOs). In this combined system, excess runoff from a rain or snow melt event may cause untreated sewage to be discharged directly to surface waters. The City of Sault Ste. Marie has fourteen CSO outfalls. Seven of the outfalls discharge directly to the St. Marys River, six discharge to the Edison Sault Power Canal and one discharges to Ashmun Creek. The number of sewage bypasses varies among the different outfalls in the city. Some of the outfalls discharge during every storm event while others rarely discharge.

Currently there are no estimates of pollutant loads to the St. Marys River from these CSO discharges. However, the city is required by the terms of its National Pollutant Discharge Elimination System (NPDES) permit to implement a long term monitoring program on or before December 31, 1990, which will document rainfall, the frequency and duration of discharge events, and estimate the volume and quality of discharges. Results are to be submitted monthly to the Surface Water Quality Division District Office. The City began monitoring in 1991 but the results were not available in time for inclusion into the Stage I document.

A study completed in 1978 indicated that there were no adverse impacts from these CSOs on river water quality (UGLCCS 1988). However, data collected in 1986 and 1987 under the OMOE MISA pilot site study indicated that the CSOs in the Edison Sault Power Canal caused a major increase in fecal coliform bacteria densities immediately downstream in the river (UGLCCS 1988). Recent monitoring has shown localized areas of high fecal coliform concentrations, and total body contact advisories are issued periodically by the Chippewa County Health Department after bypass events.

The State is requiring that the city develop and implement a program to eliminate or adequately treat CSO discharges (see Section 4.3.2.2). The city's NPDES permit requires that a Final Combined Sewer Overflow Control Program, including an implementation plan, be submitted and approved on or before December 31, 1992. This plan will result in the elimination or adequate treatment of combined sewage discharges containing raw sewage and compliance with the Water Quality Standards.

8.3.2 Urban Runoff

8.3.2.1 Ontario

Marsalek and Ng (1989) define urban runoff as "...a non-point source of pollution which is discharged into the receiving waters in two forms, either as stormwater discharges from storm sewers, or overflows from combined sewer systems." Surface drainage in the City of Sault Ste. Marie is provided by storm sewers which discharge either directly into the St. Marys River or into one of a number of creeks draining into the river.

Marsalek and Ng (1987, 1989) calculated the loadings of 17 organic and inorganic contaminants to the St. Marys River via urban runoff from the City of Sault Ste. Marie during 1985/1986. Runoff loadings of each parameter except chloride were calculated for specific land use areas, utilizing mean concentrations and runoff volume, and then summed for each land use area to estimate total loadings to the river. Chloride originates primarily from winter road salting, and concentrations in runoff are therefore highly variable. Loadings were estimated from road salt usage records, assuming that all salt is washed off by runoff (Marsalek and Ng 1989).

OMOE monitors snow dump sites each year with soil surveys. Sodium and chloride levels in soils in 1989 and 1990 were found to be higher at the dump sites than at control sites. Vegetation in close proximity to the snow dump sites does not exhibit phytotoxic symptoms from runoff (R. Stewart, OMOE Sault Ste. Marie, pers. comm.).

Annual runoff was estimated from mean annual precipitation using the STORM model. Total stormwater discharges for the Sault were calculated to be 13.0×10^6 m^3/yr (Marsalek and Ng 1989). The collection area for urban runoff is 4,500 ha. Runoff (and snow meltwater) was sampled at 3 sites representing residential, commercial and industrial areas.

The results of the loading calculations for stormwater runoff in Sault Ste. Marie are presented in Table 8.8. Daily loadings are shown in Table 8.8 in order to provide a basis for comparison with the other point and non-point sources. In reality, loadings from stormwater occur only as a result of rainfall events such that the total loading over a one year period represents the sum of all rainfall events.

In comparing these non-point loadings with municipal and industrial point sources (based on data taken from UGLCCS 1988), Marsalek and Ng (1989) concluded that, for the majority of parameters, the point source loadings dominated the total loadings. Point sources contributed up to 90 percent of ammonia, phosphorus, iron, mercury, zinc, phenols, cyanide, oil and grease and chloride. Stormwater runoff, however, contributed the largest loadings (greater than 50 percent of the total) of cobalt, copper, cadmium, PCBs and HCB. Cobalt and PCB loadings to the St. Marys River were entirely derived from stormwater. Loadings of HCB were also derived entirely from stormwater; however, the total amount contributed was very low (0.002 to 0.006 kg/yr, Table 8.8). Although less than 50 percent of the total, stormwater also contributed relatively large loadings of chloride, lead and nickel (~40 percent), and PAHs (~30 percent).

8.3.2.2 Michigan

Urban runoff is discharged to the St. Marys River via storm drains and CSOs (see Section 8.3.1 for more information on CSOs). There are 34 storm drains in Michigan discharging to the St. Marys River. Eight storm drains discharge directly to the St. Marys River, 15 discharge to the Edison Sault Electric Company Power Canal, and 11 discharge to three minor tributaries including 2 to Seymour Creek, 7 to Ashmun Creek and 2 to Mission Creek. No storm drain loading estimates are available.

8.3.3 Rural Runoff

Rural runoff may be a source of sediments, nutrients and pesticides and atmospherically derived trace metals and organic contaminants to the St. Marys River. Soil erosion contributes both to higher sedimentation rates and to increased nutrient loads to the river.

Table 8.8 Summary of loadings in urban runoff from the Sault Ste. Marie,Ontario area during April 1985 to November 1986 (Marsalek and Ng 1987, 1989).

Parameter	Stormwater (kg/yr)	Stormwater (kg/d)
Ammonia (N)	9,800	26.8
Phosphorus	4,100	11.2
Chloride	1,850,000 3,700,000	5,068 10,137
Cadmium	2.0 78.0*	0.0055 0.0214
Cobalt	0 263 (46)*	0 0.721
Copper	572	1.57
Iron	92,100	252.3
Lead	1,550	4.25
Mercury	0.4	0.0011
Nickel	114 338	0.395 0.926
Zinc	3,660	10.03
Oil and Grease	33,300	91.2
Total Phenols	196	0.537
Cyanide	27	0.074
HCB	0.002 0.006	0.000005 0.000016
Total PCBs	0.4 3.2	0.0011 0.009
PAHs (17)	122 238	0.334 0.652

* Loadings calculated from data above the detection limit. At some sites large variations in concentration and/or a significant percentage of the data was below the detection limit and thus two loading estimates, low and high are given.

Daily loadings have been calculated assuming that annual loadings were uniformly distributed throughout the year.

8.3.3.1 Ontario

No estimates of soil erosion or loadings from rural runoff have been made for Ontario.

8.3.3.2 Michigan

Annual soil erosion from the St. Marys River geographic area is estimated to be 173,889 tonnes, including 1.18 tonnes of phosphorus (UGLCCS 1988). Additional sources of nutrients include livestock operations (contributing an estimated 5.18 tonnes of phosphorus to the St. Marys River each year) and commercial fertilizers (no estimates of loads to the St. Marys River) (UGLCCS 1988).

8.3.4 Atmosphere

The atmosphere can be a source of contaminants to aquatic ecosystems through deposition of wet and dry materials falling directly on water surfaces including upstream water bodies. Contaminants deposited by the atmosphere can subsequently be transported downstream in watersheds. As well, contaminants may be indirectly deposited in the watershed and exported into the St. Marys River. Direct deposition of contaminants to the river is likely to be limited because of the relatively small surface area of water. However, deposition to Lake Superior, its watershed and the St. Marys River immediate watershed are likely to be a significant source of contamination. Materials deposited in the watershed will likely be represented in the loadings calculated for urban runoff (Table 8.8) and rural runoff in Michigan (section 8.3.3).

Although considerable attention has been focused on acid inputs to aquatic systems from the atmosphere ("acid rain"), much less is known about atmospheric loadings of contaminants and trace elements (Johnson *et al.*, 1988). Numerous organic and inorganic contaminants have been detected in rain, snow, vapour and dry fallout i.e. Cu, Ni, Zn, Pb, Cd, Hg, P, N, PCBs, DDTs and a wide variety of organic compounds (Johnson *et al.*, 1988; Eisenreich *et al.*, 1981; Strachan and Huneault 1979; and Johnson 1987). Strachan and Eisenreich (1988) concluded that there are insufficient data available to reliably estimate the relative importance of atmospheric deposition of most of these contaminants to the Great Lakes or for the preparation of mass balances. However, the contribution of contaminant loadings from atmospheric deposition will be significant because of the large fraction of pollutants likely to enter Lake Superior from the atmosphere (S. Eisenreich, pers. comm).

8.3.4.1 Ontario

Estimates of atmospheric loadings to the St. Marys River AoC were attempted for the UGLCCS (1988) for 17 PAHs. Boom and Marsalek (1987) collected 20 snowpack samples located in a grid centred around the City of Sault Ste. Marie, Ontario (4,500 ha) to establish the areal distribution of PAH depositions during the winter of 1986/1987 (Figure 8.11).

The areal distribution of PAH loadings (Figure 8.11) in the snowpack tends to indicate that industrial emissions are the main source of PAHs to this area, with the highest loadings observed immediately downwind from the steel plant. Chemical finger printing indicated that the westerly stations were dominated by steel plant emissions, with the easterly stations being influenced by the other urban sources. The total quantity of the 17 PAHs deposited and stored in the snowpack in the study area was estimated to be about 18 kg for the 11 week accumulation period. PAHs stored in the snowpack are quickly released during the snowmelt period and thereby create a shock loading to the receiving waters (Boom and Marsalek 1987). The average concentrations of total PAHs in fully mixed meltwater from the study area was estimated to be about 3 μg/L.

Although the data base refers to winter conditions, the industrial contribution to PAH deposition is not expected to vary seasonally (Boom and Marsalek 1987). Hence, the annual PAH loading extrapolated from the 2.5 month accumulation would be nearly 90 kg/yr (0.25 kg/day). Based on this annual loading, estimates of annual atmospheric deposition rates (expressed in kg/day) for the most common PAHs found in the snowpack are provided in Table 8.9. It should be noted that a large part of this loading will fall on pervious ground, and the PAHs may be adsorbed onto soil particles, thereby being immobilized.

Table 8.9 Estimated annual loadings (kg/d) of six PAH compounds calculated from snowpack measurements over a 2.5 month period November 15/1986 to February 24/1987 (from Boom and Marsalek 1987).

Parameter	Minimum	Maximum
Phenanthrene	0.0373	0.0597
Fluoranthene	0.0471	0.0742
Pyrene	0.0285	0.0463
Benzo(a)pyrene	0.0041	0.0142
Benzo(b)fluoranthene	0.0041	0.0142
Benzo(k)fluoranthene	0.006	0.0156
Total Six PAHs	0.127	0.224

The total loadings for these six PAHs are approximately one third that measured by Marsalek and Ng (1987, 1989) for the stormwater loadings of 17 PAHs (Table 8.8). Although it is not known whether the six PAHs measured in the snowpack had equivalent concentrations as the same compounds measured in the stormwater, the magnitude of the loadings are similar and may indicate that the stormwater loadings originate primarily from local atmospheric emissions. The total loadings to the river would thus be greater than that estimated for stormwater runoff from the urban area because atmospheric dispersion would result in contamination of snow and precipitation over a much larger area. Current data are sufficient to estimate atmospheric inputs to the Great Lakes for PCBs, DDT, benzo(a)pyrene and lead. The loadings calculated by Strachan and Eisenreich (1988) for Lakes Superior and Huron are shown in Table 8.10. The St. Marys River AoC contributes to the loading to Lake Huron. Direct atmospheric loadings are those delivered to the surface of the lake, whereas indirect loadings are those which fall upstream of Lake Huron and would include inputs from the St. Marys River and Lake Superior.

The loadings shown in Table 8.10 suggest that atmospheric loadings are a major non-point source of lead, PCBs and PAHs (benzo(a)pyrene) to the St. Marys AoC (indirect loadings) as well as to Lakes Huron and Superior (direct plus indirect loadings). Some investigators have speculated that there are seasonal variations however, for the purpose of estimating loadings for the RAP, it has been assumed that there is no variation.

Although not directly comparable, total indirect atmospheric loadings to Lake Huron (including the St. Marys River AoC watershed) are at least an order of magnitude higher for lead and PCBs than those contributed by urban runoff to the St. Marys River from Sault Ste. Marie, Ontario (Table 8.8).

A more accurate assessment of the atmospheric deposition of 14 pollutants to the Great Lakes will be complete in 3 years (Eisenreich pers. comm). Historic loadings will be approximated using sediment core profiles.

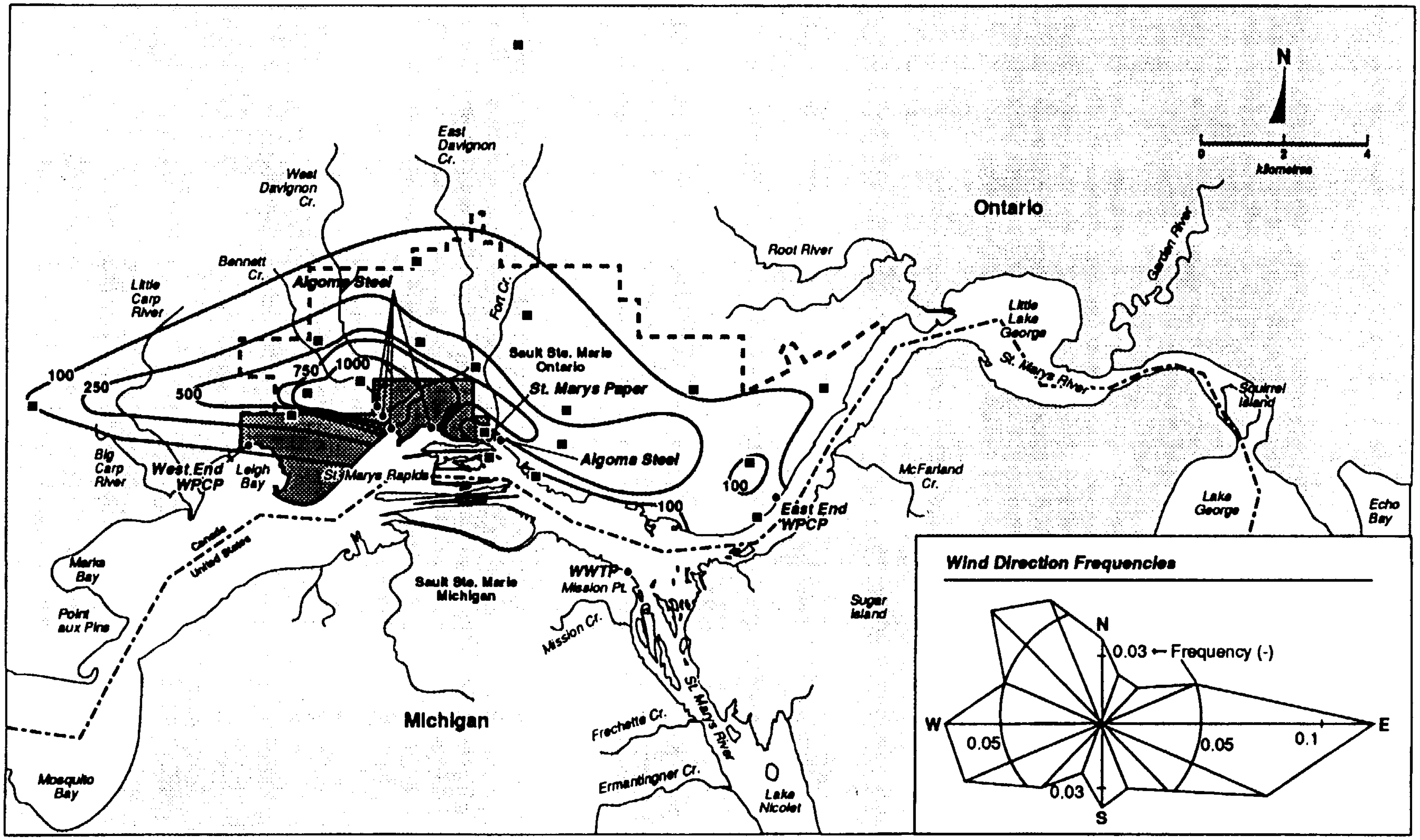
An atmospheric monitoring network for organic contaminants in the Great Lakes consisting of four stations was described by Chan and Perkins (1989). Contaminants monitored were organochlorine pesticides, PCBs and 12 PAHs. The closest station to Sault Ste. Marie is located on Manitoulin Island at South Baymouth.

Figure 8.11

St. Marys River Remedial Action Plan

Urban snowpack total PAH loading contours and wind direction frequencies for Sault Ste. Marie, Ontario during the period November 15, 1986 to February 24, 1987

(adapted from Boom and Marsalek 1987)



- - - study area boundary

steel company properties

● point source discharge location

■ sampling station

1000 isoloading contours (µg/m²)

Based on one year of sampling (1988-1989), the volume-weighted mean and the range of concentrations for phenanthrene, fluoranthene, pyrene, total PAHs and total PCBs at this station are provided in Table 8.11. The authors did not calculate loadings.

Volume-weighted mean concentrations of organochlorine pesticides ranged from a high of 9.64 ng/L for α-hexachlorocyclohexane (α-BHC) (18 samples) to a low of 0.01 ng/L for p,p'TDE (1 sample). Concentrations of the 3 PAHs and total PAHs (in Table 8.11) at the South Baymouth station were the highest of all 4 stations in the network. Chan and Perkins (1989) note that PAHs are primarily affected by urbanization and industrial sources but suggested that higher concentrations in more remote locations may be due to localized effects from domestic wood burning.

Environment Canada and OMOE have also established an air and precipitation monitoring network for toxics in southern Ontario (Shackleton et al. 1989). The station closest to the St. Marys River AoC is located 60 km north of the Sault at Turkey Lakes. Contaminants which are monitored include PCBs, chlorinated pesticides, trace metals and dibenzodioxins and dibenzofurans. Although the Turkey Lake Research Centre has been in operation since 1980, the network for monitoring the above contaminants in air and precipitation has only recently been established and thus data are preliminary.

Mean concentrations and ranges for HCB, PCBs and α-BHC are provided in Table 8.12. Precipitation statistics represent 12 samples collected over one year (April 1988 to April 1989), whereas the air data summarize 16 samples collected during 8 months (September 1988 to April 1989).

The mean concentration of total PCBs in precipitation at the Turkey Lakes station is approximately 3 times the mean of the South Baymouth station reported by Chan and Perkins (1989). The cause of the higher concentrations at the Turkey Lakes station is not known. However, Johnson *et al.*, (1988) indicated that more than 90% of the loadings to the Turkey Lakes for PCBs, α-BHC, r-BHC, methoxychlor, HCB and dieldrin was from direct precipitation.

Trace metals also are contributed by the atmosphere (Renber 1988 and Johnson 1987). In Ontario lakes, Johnson (1987) found anthropogenic loadings of Zn, Cd, Hg, and As which were 1.8 to 2.6 times background loadings. The atmosphere was the primary contributor of these anthropogenic sources. In the Turkey Lakes, Johnson *et al.*, (1988) found fish body burdens of Hg to be correlated with atmospheric loading, thus the high body burdens of Hg in walleye in Lake Munuscong may be at least in part related to atmospheric loading.

Based on the above data, atmospheric contributions of PCBs, PAHs, lead, Hg and organochlorine pesticides serve as a major loading source to the Great Lakes in general. Of these parameters, Sault Ste. Marie area sources likely contribute to the total atmospheric loading of PAHs; however, the data base is not sufficient to fully quantify individual source contributions to inputs to the St. Marys River or other downwind locations. A full evaluation of fugitive PAH emissions to the atmosphere including near- and far-field deposition patterns and loadings is required.

8.3.4.2 Michigan

There are no major near-field industrial sources of atmospheric contaminants on the Michigan side of the St. Marys River.

8.3.5 Contaminated Sediments

Studies have shown that polluted sediments have a direct impact on associated biota and can be significant sources of contaminants to both the water column and aquatic organisms. Furthermore, such sediments can

Table 8.10 Direct and indirect atmospheric loadings to Lakes Huron and Superior and their percent of total loadings (Strachan and Eisenreich 1988).

Parameter	Direct		Indirect	
	kg/day	% of Total Loadings	kg/day	% of Total Loadings
Lake Huron				
PCBs	1.09	63	0.26	15
DDT	0.18	72	0.063	25
Benzo(a)pyrene	0.50	63	0.135	17
Lead	1,107	94	47	4
Lake Superior				
PCBs	1.50	90		
DDT	0.25	97		
Benzo(a)pyrene	0.19	96		
Lead	641	97		

Table 8.11 Mean and range of concentrations for selected PAHs, total PAHs (12) and total PCBs measured in precipitation at South Baymouth, Manitoulin Island (from Chan and Perkins 1989).

Parameter	n	Mean (ng/L)	Range (ng/L)
Phenanthrene	14	132.3	9.9-1,233
Flouranthene	15	149.7	19.8-798.8
Pyrene	12	99.7	19.6-534.2
Total PAHs	16	459.1	93.0-2,689
Total PCBs	18	8.12	0.8-32.3

Table 8.12 Mean concentrations and ranges for selected organochlorine contaminants measured by OMOE at the Turkey Lakes station, north of Sault Ste. Marie (from Shackleton et al. 1989).

Parameter	Precipitation (ng/L)		Air (ng/m^3)	
	Mean	Range	Mean	Range
HCB	0.12	0-0.80	0.05	0-0.12
Total PCBs	21.7	0-105	0.18	0-0.66
α-BHC	1.65	0-8.3	0.13	0-0.31

continue to be a source long after the external inputs (point and non-point) have been eliminated. However, the actual amounts of contaminants released from the sediment to the water column and organisms of the St. Marys River have not been quantified (UGLCCS 1988).

Although it has not been documented, it is suspected that cargo vessel passage will result in some degree of sediment resuspension. Shipping may thus exacerbate contaminant recycling and promote redistribution of contaminated sediments.

8.3.6 Groundwater Contamination/Waste Disposal

8.3.6.1 Ontario

Three sources of potential groundwater contamination have been identified in Ontario: the Algoma Steel Slag Site; the Sault Ste. Marie (Cherokee) Landfill; and the site of a former coal gasification processing plant.

(1) The Algoma Steel Slag Site was characterized as having the potential to impact human health and safety. At this site, approximately 718,600 tonnes of solid waste and 66,800 tonnes of liquid waste are disposed each year. The predominant waste is slag from iron and steel operations. However, lime, industrial refuse, waste acid and oil, coke oven gas condensate, and sludge are also disposed on the site (Beak 1988). According to LaHaye (1990) oil and coke oven gas condensate are no longer disposed of at the slag dump.

In early 1988, OMOE initiated a two year comprehensive investigation to: i) quantify the degree of waterborne contaminants migrating from the site; ii) identify their significant pathway(s); and iii) compare contaminant loading rates from the "uncontrolled" sources to those associated with monitored effluent discharges from the Algoma Steel plant. The following preliminary conclusions were identified in the interim report of this study (Beak 1989). The final report has not been released for incorporation in the Stage I document. Final results will be presented in Stage II.

An inventory of wastes and by-products on-site as well as leachability tests conducted on selected materials indicate that the constituents of environmental concern are phenols, PAHs, volatile aromatics, cyanide, ammonia, metals and acid.

The configuration of the water table is controlled by the relief of the ground surface underlying the slag material. Shallow groundwater flow is radially outwards from the original topographic high, which is centred under the slag dump. Although the shallow groundwater system is recharged by infiltration, upwardly-directed gradients exist, discharging groundwater directly into the St. Marys River, Baseline Road ditch and West Davignon Diversion Channel (peripheral creeks). Local recharge occurs at the oil pond and pickling liquor disposal sites.

Three areas have been identified as sources for groundwater constituents: the central slag area (comprised of acid dump, sludge dump, oil pond and filter cake dump); the former Domtar facility and surrounding area; and the dredged river sediment disposal area. "Sulphate and chloride plumes emanate from the central slag area as a result of the disposal of slag, lime fines and pickling liquor" (Beak 1989). Phenols and PAHs are associated with all three source areas, while volatile organics are associated with the central slag and Domtar areas. Metals are associated with the main slag area and dredged river sediments. However, the mobility of many metals is restricted by the high pH of the groundwater in most areas of the site.

Seepage of groundwater through the St. Marys River bed has been confirmed at two offshore sites adjacent to the Algoma slag site. These sites were found to have sediment electrical conductance significantly elevated over background. The chemistry of water obtained from river bed mini-piezometers was comparable to groundwater obtained from adjacent on-site piezometers (Beak 1989).

The surface water study confirmed that there was little possibility of overland runoff on the slag site. The peripheral creeks (ditches and streams) are the only significant pathways for contaminants to leave the site via surface water.

Approximately 90 percent of the groundwater discharge to the St. Marys River and creeks adjacent to the site occurs through the slag, because the underlying geologic material is much less permeable than the slag.

During low flow conditions, most of the flow through Baseline Road ditch and the West Davignon Diversion Channel can be attributed to groundwater discharge from the slag site. Only 7 percent of the total flow in Bennett Creek is attributed to groundwater discharge from the slag site. Water flow to the St. Marys River from surface water discharge and discharge directly to the river along the slag site shoreline are approximately equal.

Significant mass is contributed to the St. Marys River as dissolved creek loading and by groundwater discharge along the river shoreline. Preliminary loading estimates are outlined in Table 8.13. Ongoing data collection for the study will help verify these initial estimates.

Table 8.13 Comparison of loadings (kg/d) to the St. Marys River by direct groundwater discharge, indirect stream flow and direct Algoma plant effluent (modified from Beak 1989).

Source	Loadings (kg/d)				
	Chloride	Sulphate	Iron	Phenols	Dissolved Organic Carbon
Groundwater Discharge Along the Shoreline	249.32	986.3	0.27	0.04	19.18
Dissolved Load in Creeks	139.73	52.05	1.75	0.01	2.71
Algoma Plant Effluent Outfalls	18,885*	768†	2,321†	160†	NA

NA - Data not available
* UGLCCS (1988)
† OMOE (1989b)

These preliminary results indicate that loadings of phenols and iron to the river from the slag site are extremely small relative to point sources such as Algoma Steel outfalls. Loadings of sulphate, however, are high compared to those derived from Algoma's outfalls. The loadings of iron contributed from the slag site are also low relative to those derived from tributaries which ranged from 6.63 to 125.42 kg/d (Table 8.7).

(2) The second site in the area, the Sault Ste. Marie (Cherokee) Landfill is a 56.6 hectare site located at the northeast end of the city of Sault Ste. Marie. This landfill is licensed to handle municipal waste composed of 60 percent domestic waste (200 tonnes/d), 10 percent commercial waste (35 tonnes/d) and 30 percent sewage sludge (100 tonnes/d). A proposed expansion of the landfill resulted in an environmental assessment. The landfill is drained by Cannon Creek to the north and west, which is a tributary to the Root River which drains into the St. Marys River. Hydrogeologic studies showed that shallow ground water flow is from north to south. In the north-most portion of the site infiltrating groundwater recharges into deeper stratigraphic units, and in the centre of the site horizontal shallow ground water flow occurs. A groundwater monitoring network identified an on site leachate plume flowing towards the Root River (Non- Point Source Work Group 1988). An application for a Certificate of Approval for a leachate collection system has been submitted to the Ministry of the Environment along with a request for Provincial funding (LaHaye 1990).

The Cherokee Landfill is believed to have a negligible impact on surface waters of the St. Marys River (UGLCCS 1988).

(3) Coal gasification plant. Manufactured gas plants produced gas for illumination and heating in Ontario from about 1850 to the late 1950's, mostly by carbonization of coal. In addition to combustible gas, these plants produced by-products, such as tars, sludges, liquors and other gas cleaning wastes most of which were left in buried containers at the plant site or transported to waste disposal sites. These wastes are environmentally hazardous because they are contaminated with PAHs, phenols, light aromatics, cyanide, inorganic sulphur, nitrogenous compounds and metals.

In 1986, buried wastes containing coal tar were discovered at the site of a manufactured gas plant in Ottawa. The discovery of these wastes prompted OMOE to commission a study to identify and provide a preliminary assessment of manufactured gas plant sites in the Province of Ontario. The resultant report by Intera Technologies Ltd. (1987) identified forty-one sites in Ontario including one which was located on the southwest corner of Goulais Avenue and Bonney Street, Sault Ste. Marie.

The 1987 study reported that this former gas plant site is currently an uncontrolled access parking lot owned by Algoma Steel Corp. Adjacent property use is primarily industrial with some residences located north of the site. There is no available history of excavation at the site, other than installation of water mains and sewers along adjacent streets. The closest surface water body is East Davignon Creek located 100 m to the southeast. This was the only gas plant site not inspected for the 1987 survey.

The report, dated April 1987, stated that no significant environmental impact or adverse health effects are perceived to exist at this site. Spent oxide wastes containing up to 1.2 percent total cyanide were found at the gas purification plant site. Tests carried out by OMOE determined that the cyanide residues were not leachable (LaHaye 1990). (Note: The Domtar facility and surrounding area has been included in the Beak (1989) slag dump study).

No loading estimates are available for contaminants derived solely from the coal gasification site. However, loading estimates currently being developed as part of the Beak (1989) investigation of the Algoma Slag Site will include contributions from the coal gasification site (Table 8.13).

8.3.6.2 Michigan

The total Michigan groundwater discharge to the St. Marys River is estimated at 2.156 cubic meters per second and contributes approximately 0.1% to the total flow of the river (UGLCCS 1988). Well water sampling in and around areas of known and potential contamination indicates that Cannelton Industries Site and the 753 Radar Site area are sites which may potentially cause significant local impacts on the water quality or sediments of the St. Marys River. Impacts could occur through a combination of groundwater discharge, surface runoff and erosion of contaminated soils and waste into the river.

Potential minor impacts on the river from groundwater contamination are posed by the 753 Radar Site and the Superior Sanitation 3 Mile Site which contains municipal and light industrial refuse as well as sludges from the Sault Ste. Marie Wastewater Treatment Plant.

Waste Disposal Sites

There are seven waste disposal sites, three municipal and four industrial, in Michigan within the immediate watershed of the St. Marys River AoC. The municipal sites include the Dafter, Bay Mills and Superior Sanitation-Rudyard landfills. Three industrial sites, Cannelton Industries, Union Carbide and the Superior Sanitation 3 mile site are on Michigan's Priority List for Evaluation and Interim Response (Act 307 List). The Soo Line Railroad waste site contains mostly construction and demolition debris.

The Dafter Landfill is currently the only active site. It is licensed to take domestic and general municipal wastes, light industrial refuse and sludge from local wastewater treatment plants. During 1989, more than 25 samples were collected from monitoring wells located around the landfill. No evidence of groundwater contamination by the landfill was found (MDNR unpublished data). Dafter landfill was not a source of pollutants to the groundwater or to the St. Marys River.

The Bay Mills Township Sanitary Landfill was closed in mid 1991. It accepted municipal wastes and has three monitoring wells located east, south and west of the site. Well monitoring data from July and October 1989 indicate that the Bay Mills Landfill was not impacting groundwater or the St. Marys River at that time.

The Superior Sanitation-Rudyard Landfill was closed in early 1990. The landfill accepts municipal wastes and has six monitoring wells; three upgrade and three downgrade of the site. Well monitoring data from June and August 1989 showed no decline in water quality between upgrade and downgrade wells and the landfill was not contributing pollutants to the groundwater or St. Marys River. In 1991 the Anderson Corporation purchased the Superior Sanitation-Rudyard Landfill and installed additional monitoring wells and a new leachate system in anticipation of re-opening the site.

The Soo Line Railroad waste site is located approximately 800 metres from the St. Marys River and contains construction and demolition debris trees, stumps and other inert wastes (UGLCCS 1988).

Sites of Environmental Concern

The Cannelton Industries Site is located approximately 3 km west of Sault Ste. Marie. The northern boundary of the site borders the St. Marys River. The site occupies approximately 30.6 hectares and is presently vacant. The site was once owned by Northwestern Leather Company which operated a tannery on the site from 1900 to 1958 and tannery wastes were discharged or deposited to a low-lying wetland along the St. Marys River. The tannery dump site includes a barren zone of approximately 0.4 hectares, completely devoid of vegetation and with varied soil colours.

The Cannelton Industries site has been designated a Federal Superfund Site and a Michigan Act 307 site. mitigation measures have been initiated. In 1991, it has been ranked 11th out of 748 (MDNR 1991) in Michigan's Group 1 list.

Soil samples from within the barren zone and from areas immediately adjacent to the zone indicate the soils are contaminated with several inorganic compounds: arsenic, cadmium, chromium, copper, lead, zinc and cyanide. Sampling has repeatedly demonstrated extreme chromium concentrations (with whole percentages and as high as 290,000 ppm (Elaine Pelc, MDNR, Environmental Response Division, pers. comm.).

The Cannelton Industries site is a source of chromium in sediments along the U.S. side of the St. Marys River. U.S. EPA completed a remedial investigation (RI) as part of superfund activities at the Cannelton Industries Site in 1991. U.S. EPA conducted sampling of soil, sediment, groundwater, and surface water on and near the site. Soil samples confirmed levels of chromium and other inorganic contaminants found in earlier studies and further defined the extent of contamination at the site (Elaine Pelc, MDNR, Environmental Response Division, pers. comm.). Concentrations of chromium in the sediments ranged from 3.65 to 16.25 mg/kg upstream of the site and up to 31,000 mg/kg downstream of the site. The highest concentrations of chromium in the sediments were found in the small bay west of the coal dock, downstream from the Cannelton Industries site (designated "Tannery Bay" in the RI report) (U.S.EPA 1991). Surface water concentrations ranged from "not detected" to 1.2 μg/L upstream of the site. Samples collected adjacent to and downstream of the site ranged from "not detected" to 485 μg/L in an unfiltered water sample. The highest concentrations of chromium in the surface water were found off the point designated as "Tannery Point" in the RI (U.S. EPA 1991). Only two of seventeen samples exceeded the State of Michigan's Rule 57(2) allowable level.

The superfund RI report also indicated that the Cannelton Industries site may not be a significant source of chromium contamination through the discharge of contaminated groundwater. Of 62 groundwater monitoring wells, only seven have shown detectable levels of chromium, with a maximum concentration of 79.5 $\mu g/L$.

Chromium concentrations in bottom sediments ranged from 8 to 10 mg/kg at uncontaminated sites and from 20 to 2,200 mg/kg nearshore and downstream of the Cannelton site. Concentrations in sediments immediately adjacent to the site were as high as 4,000 mg/kg (Kenaga 1979). However, with the exception of one station with a chromium concentration of 40 $\mu g/l$, chromium was not found in water samples above the analytical detection levels (Kenaga 1979).

Interim containment actions implemented by Cannelton Industries include fencing the barren zone to limit access; construction of an erosion control structure on the bank of the St. Marys River; and installation of a sprinkler system over the barren zone, to temporarily mitigate the threat of fires in the area.

The Union Carbide disposal site is a waste pile approximately 800 meters long and 45 meters high, unlined and uncovered. The wastes are from the Union Carbide's former production facility and are primarily calcium carbonates with minor amounts of heavy metals and cyanide, along with varying amounts of demolition debris. The Union Carbide waste pile is a Michigan Act 307 site ranked as number 182 out of 567 in Michigan's Group 1 list in 1989 (MDNR 1989). Groundwater contamination is not indicated in the Act 307 Listing (MDNR 1989). There are no monitoring wells at the site. The site was rescored in 1991 and ranked 90 out of 748 sites (MDNR 1991).

The Superior Sanitation 3 Mile Site accepted municipal and light industrial refuse and is now closed. Following closure, the landfill was covered with a clay cap and six monitoring wells were installed. Based on limited monitoring data, there seems to be an effect on groundwater due to the landfill, but the degree of contamination is unclear. The landfill may be a potential (though unlikely) source of trichloroethene, trichloroethane and perchloroethene contamination in nearby residential and public supply wells (Mark Petrie, MDNR, Environmental Response Division, pers. comm.). The Superior Sanitation 3 Mile Site is a Michigan Act 307 site ranked as number 490 out of 567 sites in Michigan's Group 1 list in 1989 (MDNR 1989). The site was not rescored in 1991.

The former 753 Radar Station Area is a Michigan Act 307 site and in 1989 was ranked 208 of 567 in Michigan's Group 1 list (MDNR 1989). Groundwater at the site is contaminated with lead, PCE, TCE and TCA. The U.S. Army Corps of Engineers (USACOE) is responsible for site cleanup and has produced a hazardous and toxic waste evaluation. They are currently proceeding with the cleanup.

8.3.7 Shipping

8.3.7.1 Ontario

The average number of vessels passing through the locks decreased from 26,122 vessels in 1953 to 12,712 in 1970, and to 8,345 in 1986. The Canadian locks are no longer operational due to structural wall failures. The vessels carry mainly crude oil, grain, steel, coal, petroleum products, taconite and iron ore between Lake Superior and the industrial centres on the lower lakes (UGLCCS 1988).

It is recognized that transient river traffic can act as a source of contaminants to the St. Marys River. 1987 to 1990 information from the Canada Coast Guard (CCG) gives a non-quantified indication of the frequency of ship-based spills that may occur in the St. Marys River:

- 1987 191 pollution incidents were reported in the CCG Great Lakes Region. Of these reported incidents, a total of 10 occurred in the St. Marys River. Eight were identified as shore based incidents and 2 were mystery sources. All of the oil sheen occurrences originated from shore based sources.

- 1988 155 pollution incidents were reported in the CCG Great Lakes Region. Of these reported incidents, a total of 5 occurred in the St. Marys River. Two were identified as shore based incidents, 2 were mystery sources and one incident did not contain contaminants. None of the reported incidents were petroleum.

- 1989 219 pollution incidents were reported in the CCG Great Lakes Region. Of these reported incidents, a total of 21 occurred in the St. Marys River. Thirteen of these incidents were oil sheens of which 7 were shore based and 6 were mystery sources. There was one ship based spill where calcium chloride was released into the St. Marys River.

- 1990 217 pollution incidents were reported in the CCG Great Lakes Region. Of these reported incidents, a total of 7 occurred in the St. Marys River. Fiver were identified as shore based incidents, 1 was a mystery source and 1 was ship based. Three of these spills were petroleum related, 2 were land based and one was a result of bilge from a tug.

Discharges of oil which could be recovered from the water were recovered. Light sheens of gasoline and diesel are impossible to recover but evaporate quickly (R. Quick, CCG, pers. comm.).

8.3.7.2 Michigan

All river traffic now passes through the American Locks (Canadian locks are closed). The U.S. Coast Guard Station located at Sault Ste. Marie reported a total of 19 spills from vessels during the five year period from 1982 through 1986 (U.S. Coast Guard 1990). These spills occurred throughout their monitoring area which includes northern Lakes Michigan and Huron. The data provided were not sufficient to determine those vessel-based spills which occurred in the St. Marys River. Oil substances and non-contaminated water were the only substances identified in these spills.

During November, 1988 the U.S. Coast Guard received reports of four separate sightings of oil sheens on the St. Marys River (U.S. Coast Guard 1990). Quantities and sources of the oil substance(s) spilled were not determined and no clean-up was feasible. In 1989 there were three reports of oil sheens in the Michigan portion of the St. Marys River. All were traced to Canadian sources including two from Algoma Steel outfalls and one in the vicinity of Fort Creek.

8.3.8 Spills

Land-based spills can be a significant source of contamination to the AoC and may constitute a major concern. The concern is that the river may, during a short period of time, be subjected to a shock contaminant loading that may be several orders of magnitude greater than the average loading.

8.3.8.1 Ontario

A summary of spills from Ontario sources into the St. Marys River is listed in Table 8.14. Algoma Steel was responsible for a variety of these spills, and has had major phenol spills in 1983, 1985, 1988 and 1989. Data for 1987 are not available. Each spill represents a significant phenol shock loading to the river over a short period. For example, the 1983 phenol spill put about 2.4 tonnes of phenol into the river over a short period of time (3 days) which was 1 to 2 orders of magnitude greater than the normal loading from Algoma discharges at that time. In 1989 Algoma Steel had two major spills of blast furnace slurry plus two significant rinse water spills (Table 8.14).

Table 8.14 Summary of spills to the St. Marys River from Canadian sources 1983 to 1989 (UGLCCS 1988 and OMOE 1990c).

Source	Substance Spilled	Year	Amount (kg)
Algoma Steel	Phenols (2200, 1870, and 3100 ppb)	1983	NA
	De-phenolized liquor	1983	NA
	De-phenolized liquor	1983	NA
	Hydrochloric acid (500 to 1000 Igal)	1984	NA
	Liquid tar (2000 Igal)	1984	NA
	Phenols (700-1000 ppb)	1985	NA
	Terminal basin discharge and stormwater (75 Igal/d)	1985	NA
	Process wastes (suspended solids, iron)	1986	NA
	Process wastes (TSS, Fe) (3200 Igal/day)	1986	NA
	Ammonia, cyanide	1986	NA
	Phenol (2100 ppb)	1988	NA
	Coal tar	1988	7
	Steel Coolant	1988	4,500
	Rinse water	1988	427,200
	Oil	1989	400
	Oil slick	1989	NA
	Slurry	1989	250,000
	Slurry, blast furnace	1989	18,000
	Phenol (1600 ppb) 2 hrs	1989	NA
	Rinse water	1989	27,200
	Rinse water	1989	13,500
	Pickle liquor	1989	450
Algoma Central Railway	Oil sheen	1989	NA
St. Marys Paper	Sulphuric acid (45 Igal)	1985	NA
	Sulphuric acid to clear water (20,000 lb)	1986	NA
	Diesel	1988	NA
	Pulp fibre exceedence	1988	NA
	Ground wood fibre (0.4%)	1989	2.4
East End WPCP	Raw sewage	1986	NA
	Chlorinated raw sewage	1986	NA
	Raw sewage	1988	NA
	Chlorinated sewage	1988	NA
Plummer Hospital	Oil, furnace	1989	NA
	Oil, furnace	1989	3,375
Texaco	Oil, separator	1988	NA
Land	Gasoline	1988	50
Unknown Sources	Non-PCB oil	1986	NA
	Oil sheen	1988	NA
	Oil sheen	1989	NA
	Oil sheen	1989	NA
	Oil sheen	1989	NA
	Oil sheen, light	1989	NA
	Oil slick	1989	2
	Unknown material	1989	NA
Bacentry-Fish & Co.	Dead fish	1989	NA

Note: Means of ranges taken as value; NA-data not available.

8.3.8.2 Michigan

The Michigan Department of Natural Resources has a Pollution Emergency Alerting System (PEAS) which receives reports of spills, accidents, discharges and problems related to pollution. The only summary of spills reported to PEAS which is currently available for the St. Marys River covers the period January 1, 1984 through 1989 (MDNR Data Files). A total of six spills, related to the St. Marys River, were reported during this period. Four of the reported spills originated in Ontario. Michigan based spills included oil of an unknown amount and source reported on the river on April 2, 1986 and 2 to 4 litres of gasoline released from a truck into the Charlotte River on August 27, 1985. A further report of dead lake trout was recorded for Lake Munuscong on September 30, 1985 (MDNR Data Files).

The United States Coast Guard (USCG) also monitors, tracks and investigates spills in the St. Marys River. Between April 27, 1988 and August 31, 1989 six spills have been recorded by the USCG (Table 8.15) of which two were tracked to Ontario sources and the remaining four are unknown (Table 6.15).

Table 8.15 Six spills to the St. Marys River reported to the United States Coast Guard (USCG) during 1988 and 1989.

Date	Description of Pollutants	Area Affected	Source of Pollutants
04/27/88	light, oily sheen	unknown	unknown
11/02/88	light, oily sheen	Canadian power canal outfall area downstream to city hall	Possible storm drain or industrial outfall*
11/11/88	light, patchy sheen	Mission point to 1.6 km (1 mi) above 6 mile point, sighted as far upstream as Nogoma Township, Sault Ste. Marie, Ontario.	unknown
11/20/88	light, patchy sheen particles of wood	Washing up on shore just down from 6 mile point	unknown
11/22/88	light, oily sheen	Little Rapids cut from shore-to-shore down to 6 mile point; covers area from Canadian power canal to 6 mile point.	unknown
08/24/89 to 08/31/89	oily slick and white, foamy paper or fibre product	10 km (6 mi) long by 450 m (500 yd) wide traced to Algoma Steel Company outfall. Outfall discharging black slag with heavy rainbow sheen	Possible Algoma Steel Company outfall, municipal sewers or forgotten storage tank.*

* Source tracked by USCG to Canadian Source.
OMOE/Canada Coast Guard is notified for follow up.

8.3.9 Other Non-point Sources

There are numerous other suspected sources of contaminants to the St. Marys River AoC. Large amounts of herbicides, pesticides and fertilizers are applied to areas such as powerlines, railways, road right of ways, residential and commercial properties and agricultural and forested lands.

8.4 SUMMARY

Table 8.16 summarizes the major point and non-point source loading estimates available at the time of writing. This Table represents a combination of 1986 data from the UGLCCS (1988) final report and more recent point source data from 1988 and 1989. Specific parameters which were updated are noted in the footnote to Table 8.16. The original UGLCCS (1988) loadings (including total loadings to the river) are provided in Table 8.4 for comparative purposes.

Point sources continue to contribute the greatest loadings, by far, of all parameters with the exception of copper, nickel (limited data), cobalt, cadmium, PCBs and HCB. Non-point sources contribute 17% to 29% of the percent of the chloride loadings to the St. Marys River; 29% of the copper; 37% of the lead; 16% of the mercury; 25% of the zinc; up to 65% of the nickel; and between 34% and 44% of the PAHs. Atmospheric sources contribute to urban runoff loadings as well as directly to the river and tributaries. Atmospheric inputs are likely the largest non-point source of PAHs and PCBs to the St. Marys River. The relative importance of these non-point sources of PAHs are probably higher than the data suggest, as the PAH loading calculated for the East End WPCP is believed to be overestimated (UGLCCS 1988).

In total, the river is subjected to daily loadings of 23.8 tonnes of suspended solids, 29.9 to 34.9 tonnes of chloride, 3.2 tonnes of oil and grease and 2.8 tonnes of iron.

Recent loadings data (1988), in comparison to the 1986 loadings reported by UGLCCS (1988), indicate that loadings of oil and grease are at the lower range of those reported for 1986, whereas suspended solids loadings have more than doubled. Increasing TSS loads reflects higher loadings at all Ontario industrial and municipal facilities. Suspended solids loadings at the Michigan WWTP in 1988 and 1989 were less than half those of 1986 (Figure 8.7).

The only other parameter for which loadings have increased from 1986 to 1988 is total phenols. This reflects higher loads contributed from Algoma Steel.

Since 1986, point source loadings have declined for total phosphorus (by 21 percent), ammonia (3 to 37 percent), zinc (18 percent) and cyanide (12 percent). Improvements in phosphorous loadings are primarily due to reductions at the Sault Ste. Marie (East End) WPCP, whereas decreased loadings of ammonia, cyanide and zinc are mostly attributable to reductions at Algoma Steel.

Continued reductions in contaminant loadings from Algoma Steel are expected as a result of the newly installed filtration system, which commenced operation in April 1990, as a requirement of the OMOE Control Order. Loadings from Algoma Steel for 1989 and 1990 were not available for the writing of this report. However, "major reductions in suspended solids, ether solubles, cyanide and phenols have occurred in 1989 and 1990" (OMOE unpublished data) and these reductions "will have to be taken into consideration when recommendations for abatement are made" (LaHaye, OMOE, pers. comm.).

Table 8.16 Summary of Major Point, Tributary and Non-point Source Loadings to the St. Marys River (kg/day).

Major Sources	Algoma Steel	St. Marys Paper	East End WPCP	West End WPCP	Michigan WWTP	E. Davignon Creek	Fort Creek	Bennett Creek	Big Carp River	Root River	Total Point Source Loadings	Total Non-point Source Loadings	Total Loadings to St. Marys River
Oil and Grease	2,475	231	349	13	84	-	-	-	-	-	3,152.00	91.2	3,243.20
Total Phosphorus	20	4.7	54	5.5	10.5	0.8	0.41	0.07	1.86	4.70	102.54	17.56	120.10
Ammonia Nitrogen	3,806	6.0	195.5	14.8	29	5.7	1.7	2.8	3.96	21.37	4,086.83	26.8	4,113.63
Suspended Solids	8,591	5,035	1,362	113	125.7	252	829	158	2,260	3,632	22,357.70	1,400	23,757.70
Chloride	18,885	743	2,011	598	640	952	286	671	-	-	24,786.00	5,068-10,137	29,855-34,924
TKN	-	-	-	-	-	11.57	-	-	-	-	11.57	-	11.57
Copper	0*	0.33	1.4	0.20	1.08	0.05	0.24	-	0.10	0.38	3.78	1.57	5.35
Iron	2,321	8.6	42.6	5.2	3.2	6.6	29	1.99	48.03	125.42	2,591.64	252	2,843.64
Lead	4.81	0.17	1.01	0.19	0.17	0.04	0.15	-	0.12	0.66	7.32	4.3	11.62
Mercury	0.005	0.0	0.0005	0.0001	-	-	-	-	-	-	0.01	0.0011	0.0067
Zinc	24.7	0.09	1.91	0.36	0.64	0.09	0.39	0.05	0.43	2.05	30.71	10.0	40.71
Nickel	-	-	-	-	-	0.03	0.07	-	0.09	0.32	0.51	0.395-0.926	0.905-1.436
Cadmium	-	-	-	-	-	-	-	-	-	-	0.00	0.006-0.021	0.006-0.021
Cobalt	-	-	-	-	-	-	-	-	-	-	0.00	0.0-0.0721	0.0-0.0721
Cyanide	64.5	-	-	-	0.06	0.04	0.003	0.02	-	-	64.62	0.074	64.69
Phenols	160.0	0.71	0.51	0.02	-	0.21	0.04	0.08	0.08	0.28	161.93	0.53	162.46
PAHs	0.20-1.21	0.05	0.42	0.004	-	0.04	0.006	0.005	-	-	0.725-1.735	0.58-0.90	1.305-2.635
PCBs	-	-	-	-	-	-	-	-	-	-	-	0.0011-0.009	0.0011-0.009
HCB	-	-	-	-	-	-	-	-	-	-	-	0.0000055-0.000016	0.0000055-0.000016

Point source data are based on UGLCCS (1988) results for 1986 (range for PAHs at Algoma reflects the difference between UGLCCS 1986 survey results and MISA Pilot Site studies) updated with 1988 self monitoring data for St. Marys Paper (TSS) and Algoma Steel (Oil and Grease, Ammonia, TSS, Fe, Zn, CN and Phenols); 1989 self monitoring data for the East End WPCP (TSS, TP), West End WPCP (TSS, TP) and Michigan WWTP (TSS, TP, Cu, CN, Pb, Zn); and 1988-90 OMOE stream monitoring for East Davignon Creek (TP, Ammonia, TSS, Cu, Fe, Pb, Zn, Ni, CN and Phenols) and Fort Creek (Ammonia, TSS, Cu,Fe, Pb, Zn, Ni and phenols).

Non-point source data taken from UGLCCS (1988) and based on partial data bases.
* Outfall < intake
\- No Data
No data available for the following contaminants: arsenic, chromium and manganese.

Mercury is the only contaminant which contributes to fish consumption advisories in the St. Marys AoC (see Chapters 6 and 7). The largest point source of mercury is Algoma Steel (1986 data) by an order of magnitude higher than the next highest point source (East End WPCP, Table 8.16). Mercury in sediments and bedrock and contributions from the atmosphere and Lake Superior are, however, believed to be the primary cause of the fish consumption advisory (Chapter 6).

Benthos are considered to be impaired in the St. Marys AoC. Sediments contaminated with oil and grease are known to affect the presence of *Hexagenia limbata*. Algoma Steel effluents contributed 76.3 percent of the total point source loadings of oil and grease during 1988 (Table 8.16). Secondary large sources of oil and grease include St. Marys Paper (1988 data) and the East End WPCP (1986 data).

Oil and grease from Algoma Steel has also been identified as contributing to the degradation of aesthetics in the AoC.

The accumulation of PAHs in mussel tissue was also identified as a concern (Chapter 6). The greatest loadings of these compounds to the river are the point discharges from Algoma Steel and non-point urban runoff contributions (likely atmospherically derived) based on the 1986 data.

Sediments along the Ontario shore of the St. Marys River downstream from Algoma Steel to Lake George contain concentrations of iron, chromium, zinc, lead, arsenic, manganese, nickel, copper, cyanide, oil and grease, PCBs, PAHs, LOI and total phosphorus which exceed the OMOE or U.S. EPA guidelines for disposing of dredged materials in open waters. Sediments in Little Lake George, Lake George and Lake Nicolet are also show exceedences of TKN. As well, levels of benzo(a)pyrene are above the proposed IJC objective. Major sources of these parameters which likely contribute to sediment impairments are: Algoma Steel for oil and grease, cyanide, lead, mercury, zinc, iron, and PAHs; tributaries for nickel and copper; and atmospheric non-point sources for PCBs. The Sault Ste. Marie (East End) WPCP and non-point sources also contribute loadings of copper to the river. The sources of chromium and arsenic to the sediment impairments are not apparent from Table 8.16. The Cannelton Industries Site serves as a non-point source of chromium to sediments along the U.S. side of the St. Marys River.

Ambient water quality standards have been exceeded in Ontario and Michigan. Levels of dissolved oxygen, turbidity, total phenols, total and unionized ammonia, free cyanide, iron, total phosphorus total PAHs and bacteria have exceeded their respective PWQO, MWQS and GLWQA objectives and guidelines downstream of Ontario industrial and municipal sources. Cyanide levels were not exceeded in the 1986/87 OMOE survey. The major source contributing to exceedences of water quality standards in Ontario is Algoma Steel for all parameters except total phosphorus (Table 8.16). Phenols exceeded water quality standards in Michigan waters and its source has been attributed to transboundary migration. The East End WPCP is the main source for total phosphorus.

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GLOSSARY, ACRONYMS AND UNITS OF MEASURE

MEASUREMENTS & UNITS

mg/L	=	milligram per liter	=	part per million (ppm)*
μg/L	=	microgram per liter	=	part per billion (ppb)*
ng/L	=	nanogram per liter (one trillenth part of a gram)	=	part per trillion (ppt)*
pg/L	=	picograms per litre	=	part per quadrillion (ppq)
μg/g	=	microgram per gram	=	part per million (ppm)
mg/kg	=	milligram per kilogram	=	part per million (ppm)
μg/kg	=	microgram per kilogram	=	part per billion (ppb)
ng/kg	=	nanogram per kilogram	=	part per trillion (ppt)
L/d	=	liter per day		
m^3/d	=	cubic meters per day		
mgd	=	millions of gallons per day		
cfs	=	cubic feet per second		
m^3/s	=	cubic meters per second		
kg/d	=	kilograms per day		
lbs/d	=	pounds per day		
kg/yr	=	kilograms per year		
t/yr	=	tonnes per year		
uS/cm	=	microsiemens per centimeter (conductivity)		

EQUIVALENT UNITS

meter	= m	1m	= 3.281 feet
kilometer	= km	1 km	= 0.621 miles
gram	= g	1000 g	= 1 kg = 2.205 pounds
tonne	= t	1 t	= 2,205 pounds
liter (Can.)	= L	1 L	= 0.2642 gal (U.S.) = 0.2200 gal

CONVERSION TABLES

To Convert	Multiply By	To Obtain
acres	4.047×10^{-1}	hectares
acres	4.047×10^{3}	sq. meters
centimeters	3.937×10^{-1}	inches
centimeters	1.094×10^{-2}	yards
feet	3.048×10^{-1}	meters
gallons (Imp.)	1.20095	gallons (U.S.)
gallons (U.S.)	8.3267×10^{-1}	gallons (Imp.)
gallons (U.S.)	3.785	liters
gallons (Imp.)	4.542	liters
grams	1.0×10^{-3}	kilograms
grams	3.527×10^{-2}	ounces
grams	2.205×10^{3}	pounds
hectares	2.471	acres
inches	2.540	centimeters
kilograms	1.0×10^{3}	grams
kilograms	2.2046	pounds
kilograms	3.5274×10^{1}	ounces
kilometers	6.214×10^{-1}	miles
kilometers	1.0936×10^{3}	yards
kilometers	3.2808×10^{3}	feet
liters	2.642×10^{-1}	gallons (U.S.liquid)
liters	2.201×10^{-1}	gallons (Imp)
meters	3.281	feet
meters	6.214×10^{-4}	miles
meters	1.094	yards
miles	1.609	kilometers
milligrams/liter	1.0	parts/million
ounces	2.8349×10^{1}	grams
ounces (fluid)	2.957×10^{-2}	liters
parts/million	8.354	pounds/million gal.

To Convert	Multiply By	To Obtain
pounds	4.5359×10^{2}	grams
pounds	4.536×10^{-1}	kilograms
square feet	9.29×10^{-2}	sq. meters
square inches	6.452×10^{2}	sq millimeters
square kilometers	2.471×10^{2}	acres
square kilometers	1.076×10^{7}	sq. ft.
square kilometers	3.861×10^{-1}	sq. miles
square meters	2.471×10^{-4}	acres
temperature °C	(°C x 9/5) + 32	temperature °F
temperature °F	(°F-32) x 5/9	temperature °C
yards	9.144×10^{1}	centimeters
yards	9.144×10^{-4}	kilometers
yards	9.144×10^{-1}	meters

ACRONYMS

ADI	Acceptable Daily Intake: The dose that is anticipated to be without risk to humans when taken daily. It is not assumed that this dose guarantees absolute safety. The determination of the ADI is often based on the application of laboratory animal toxicity data concerning chronic (long-term) doses to the environmental doses to which humans are exposed.
Al	Aluminum
AOC(s)	Areas of Concern: Geographic locations recognized by the International Joint Commission where water, sediment or fish quality are degraded, and the objectives of the Great Lakes Water Quality Agreement of local environmental standards are not being achieved.
As	Arsenic
Ba	Barium
B(a)P	Benzo(a)pyrene
BAT	Best Available Technology/Treatment
BATEA	Best Available Technology/Treatment Economically Achievable
BCF	Bioconcentration Factor; the ratio of the concentration of a particular substance in an organism to concentration in water.
BCT	Best Conventional Technology/Treatment.
Be	Beryllium
BEJ	Best Engineering Judgement.
BHC	Benzene Hexachloride or Hexachlorocyclohexane. There are three isomers; alpha, beta, and gamma. Gamma-BHC is the insecticide lindane.
BOD	Biochemical Oxygen Demand: The amount of dissolved oxygen consumed during the decomposition of organic nutrients in water during a controlled period and temperature.
BMP	Best Management Practices
BPAC	Binational Public Advisory Committee
BPJ	Best Professional Judgement
BPT	Best Practical Treatment
Br	Bromine
BTX	Benzene, Toluene, Xylene
Ca	Calcium

CANUSLAK	(related to joint spill agreement)
Cd	Cadmium
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
Cl	Chlorine
CMR	Critical Materials Register
Co	Cobalt
COA	Canada-Ontario Agreement Respecting Water Quality in the Great Lakes.
COD	Chemical Oxygen Demand: The amount of oxygen required to oxidize completely by chemical reagents the oxidizable compounds in an environmental sample.
CofA	Certificate of Approval
Cr	Chromium
CSO	Combined Sewer Overflow; combined storm and sanitary sewer systems.
Cu	Copper
CWA	Clean Water Act
DCB	Dichlorobenzene
DDD	(1,1 -dichloro-2,2-bis (4-chlorophenyl)ethane). A natural breakdown product of DDT.
DDE	Dichlorodiphenyldichloroethylene. A natural breakdown product DDT.
DDT	Dichlorodiphenyltrichloroethane: A widely used, very persistent chlorinated pesticide (now banned from production and use in many countries).
DFO	Department of Fisheries and Oceans (Canada)
DIC	Dissolved Inorganic Carbon
DMR	Discharge Monitoring Report
DOA	Department of Agriculture (Canada)
DOC	Dissolved Organic Carbon
DOE/EC	Department of Environment/Environment Canada
EC-50	Effective concentration of a substance producing a defined response in 50% of a test population. The higher the EC-50, the less effective the substance is because it requires more material to elicit the desired response.

EMS	Enforcement Management System
EP	Extraction Procedure
EP/OR	Environmental Protection, Ontario Region, Environment Canada
EPA	Environmental Protection Agency
F	Fluorine
FDA	Food and Drug Administration
Fe	Iron
GLISP	Great Lakes International Surveillance Plan. It provides monitoring and surveillance guidance to U.S. and Canadian agencies responsible for implementing the provisions of the GLWQA that include general surveillance and research needs as well as monitoring for results of remedial actions.
GLWQA	Great Lakes Water Quality Agreement
HCB	Hexachlorobenzene
HCBD	Hexachlorobutadiene
HCE	Hexachloroethane
Hg	Mercury
HWC	Health and Welfare Canada
IJC	International Joint Commission: A binational organization established in 1909 by the Boundary Waters Treaty. Through the IJC, Canada and the United States cooperatively resolve problems along their common border, including water and air pollution, lake levels, power generation and other issues of mutual concern.
IPP	Industrial Pretreatment Program
K	Potassium
LAMP	Lakewide Management Plan
LC_{50}	Lethal concentration (by volume) of a toxicant or effluent which is lethal to 50% of the test organism over a specified time period. The higher the LC_{50}, the less toxic it is because it takes more toxicant to elicit the same response.
LD_{50}	Lethal dose which is lethal to 50% of the test organism over a specified time period. The higher the LD_{50}, the less toxic it is because it takes more toxicant to elicit the same response.
MCL	Maximum Contaminant Level

MCLG	Maximum Contaminant Level Goal
MDNR	Michigan Department of Natural Resources
MDPH	Michigan Department of Public Health
MERA	Michigan Environmental Response Act
MISA	Municipal-Industrial Strategy for Abatement: The principal goal of this program is the virtual elimination of toxics discharged from point sources to surface waters in Ontario.
Mg	Magnesium
MGD	Million Gallons Per Day
Mn	Manganese
Mo	Molybdenum
MSP	Michigan State Police
Na	Sodium
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NH_3	Ammonia
Ni	Nickel
NO_3	Nitrate
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System; a permit system limiting municipal and industrial discharges, administered by U.S.EPA and the states.
NPDWR	National Primary Drinking Water Regulation
NPS	Nonpoint Source
NSPS	New Source Performance Standards
NTU	Nephelometric Turbidity Unit
OCS	Octachlorostyrene
OMNR	Ontario Ministry of Natural Resources
OMOE	Ontario Ministry of the Environment/Environment Ontario
P	Phosphorus

PAH	Polynuclear Aromatic Hydrocarbons, also known as Polycyclic Aromatic Hydrocarbons or Polyaromatic Hydrocarbons. Aromatic Hydrocarbons composed of at least 2 fused benzene rings, many of which are potential or suspected carcinogens.
Pb	Lead
PBB	Polybromated biphenyl; used primarily as a fire retardant.
PCB	Polychlorinated biphenyls; a class of persistent organic chemicals with a potential to bioaccumulate and suspected carcinogens; a family of chemically inert compounds, having the properties of low flammability and volatility and high electric insulation quality. Past applications include use as hydraulic fluids, heat exchange and dielectric fluids; plastisizers for plastics.
PCE	Perchloroethene
PEAS	Pollution Emergency Alert System
pH	The negative power to the base 10 of the hydrogen ion concentration. A measure of acidity or alkalinity of water on a scale from 0 to 14; 7 is neutral; low numbers indicate acidic conditions, high numbers, alkaline.
PL	Public Law
POTW	Publicly Owned Treatment Works
PTS	Persistent Toxic Substance: Any toxic substance with a half-life in water of greater than eight weeks.
PWQO	Provincial Water Quality Objectives
QCB	Pentachlorobenzene
RAP	Remedial Action Plan
RCRA	Resource Conservation and Recovery Act
Se	Selenium
SDWA	Safe Drinking Water Act
SO_4	Sulphate
SPCC	Spill Prevention and Control Countermeasure
Sr	Strontium
STP	Sewage Treatment Plant
TCA	Trichloroethane
TCB	Trichlorobenzene
TCDD	Tetrachlorodibenzo-p-dioxins

TCDF	Tetrachlorodibenzofurans
TCE	Tetrachloroethene
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TOTAL DDT	Sum of DDT isomers and metabolites
TP	Total Phosphorus
TSS	Total Suspended Solids
TTBEL	Treatment Technology-Based Effluent Limitation
UGLCCS	Upper Great Lakes Connecting Channels Study
U.S.EPA	United States Environmental Protection Agency
VOC	Volatile Organic Carbon
WHO	World Health Organization
WPCP	Water Pollution Control Plant
WQBEL	Water Quality Based Effluent Limits
WQS	Water Quality Standards
WRC	Water Resources Commission
WTP	Water Treatment Plant (for drinking water)
WWTP	Waste Water Treatment Plant
Zn	Zinc

TERMINOLOGY

ABSORPTION Penetration of one substance into the body of another.

ACCLIMATION Physiological and behavioural adjustments of an organism in response to a change in environment. See also Adaptation.

ACCLIMATIZATION Acclimation of a particular species over several generations in response to marked environmental changes.

ACCUMULATION Storage and concentration of a chemical in tissue to an amount higher than intake of the chemical. May also apply to the storage and concentration of a chemical in aquatic sediments to levels above those that are present in the water column.

ACUTE Involving a stimulus severe enough to rapidly induce a response; in bioassay tests, a response observed within 96 hours is typically considered an acute one.

ACUTE TOXICITY Mortality that is produced within a short period of time, usually 24 to 96 hours.

ADAPTATION Change in the structure forms or habits of an organism to better fit changed or existing environmental conditions. See also Acclimation.

ADSORPTION The taking up of one substance at the surface of another.

AEROBIC The condition associated with the presence of free oxygen in the environment.

ALGA(E) Simple one celled or many celled micro-organisms, usually free floating, capable of carrying on photosynthesis in aquatic ecosystems.

ALGICIDE A specific chemical highly toxic to algae. Algicides are often applied to water to control nuisance algal blooms.

ALKALINITY A measurement of acid neutralization or buffering capability of a solution (See pH).

AMBIENT Pertaining to the existing/surrounding environment and its components.

AMBIENT WATER The water column or surface water as opposed to groundwaters or sediments.

AMPULES A sealed glass container of a know concentration of a substance.

ANADROMOUS Species which migrate from salt water to fresh water to breed.

ANAEROBE An organism for whose life processes a complete or nearly complete absence of oxygen is essential.

ANOXIA The absence of oxygen necessary for sustaining most life. In aquatic ecosystems this refers to the absence of dissolved oxygen in water.

ANTAGONISM Reduction of the effect of one substance because of the introduction or presence of another substance; e.g. one substance may hinder, or counteract, the toxic influence of another. See also Synergism.

APPLICATION FACTOR A factor applied to a short-term or acute toxicity test to estimate a concentration of waste that would be safe in a receiving water.

AQUATIC Living in water.

ASSIMILATION The absorption, transfer and incorporation of substances (e.g. nutrients by an organism or ecosystem).

ASSIMILATIVE CAPACITY The ability of a waterbody to transform and/or incorporate substances (e.g. nutrients) by the ecosystem, such that the water quality does not degrade below a predetermined level.

BENTHIC Of or living on or in the bottom of a water body; benthic region, benthos.

BENTHOS Bottom dwelling organisms, the benthos comprise: 1) sessile animals such as sponges, some of the worms and many attached algae; 2) creeping forms such as snails and flatworms, and 3) burrowing forms which include most clams and worms, mayflies and midges.

BIOACCUMULATION Uptake and retention of environmental substances by an organism from both its environment (i.e. directly from the water) and its food.

BIOASSAY A determination of the concentration or dose of a given material necessary to affect a test organism under stated conditions.

BIOCONCENTRATION The ability of an organism to concentrate substances within its body at concentrations greater than in its surrounding environment or food.

BIOCONCENTRATION FACTOR The ratio of the measured residue within an organism compared to the residue of the substance in the ambient air, water or soil environment of the organism.

BIOLOGICAL MAGNIFICATION The concentration of a chemical up the food chain.

BIOMASS Total dry weight of all organisms in a given area or volume.

BIOMONITORING The use of organisms to test the toxic effects of substances in effluent discharges as well as the chronic toxicity of low level pollutants in the ambient aquatic environment.

BIOTA Species of all the plants and animals occurring within a certain area or region.

CARCINOGEN Cancer causing chemicals or substances.

CHIRONOMID Any of a family of midges that lack piercing mouth parts.

CHRONIC Involving a stimulus that lingers or continues for a long period of time, often one/tenth of the life span or more.

CHRONIC TOXICITY Toxicity marked by a long duration, that produces an adverse effect on organisms. The end result of chronic toxicity can be death although the usual effects are sublethal; e.g. inhibits reproduction or growth. These effects are reflected by changes in the productivity and population structure of the community. See also Acute Toxicity.

COMMUNITY Group of populations of plants and animals in a given place; ecological unit used in a broad sense to include groups of various sizes and degrees of integration.

CONGENER A member of the same taxonomic genus as another plant or animal: Also a different configuration or mixture of a specific chemical usually having radical groups attached in numerous potential locations.

CONTAMINANT A substance foreign to a natural system or present at unnatural concentrations.

CONTAMINATION The introduction of pathogenic or undesirable micro-organisms, toxic and other deleterious substances which renders potable water, air, soils, or biota unfit for use.

CONTROL ORDER/REQUIREMENT AND DIRECTION ORDER Enforceable orders in Ontario.

CONVENTIONAL POLLUTANT A term which includes nutrients, substances which pollutant consume oxygen upon decomposition, materials which produce an oily sludge deposit, and bacteria. Conventional pollutants include phosphorous, nitrogen, chemical oxygen demand, biochemical oxygen demand, oil and grease, volatile solids, and total and fecal coliform, chlorides, etc.

CRITERIA Numerical limits of pollutants established to protect specific water uses.

CRITERION, WATER QUALITY A designated concentration of a constituent based on scientific judgments, that, when not exceeded will protect an organism, a community of organisms, or a prescribed water use with an adequate degree of safety.

CRITICAL LEVEL See Threshold.

CRITICAL RANGE In bioassays the range of magnitude of any factor between the maximum level of concentration at which no organisms responds (frequently mortality) to the minimum level or concentration at which all organisms respond under a given set of conditions.

CUMULATIVE Brought about or increased in strength by successive additions.

CUMULATIVE ACTION Increasingly severe effects due to either storage or concentration of a substance within the organism.

DENSITY Number of individuals in relation to the space.

DETRITUS A product of disintegration, defecation, destruction, or wearing away.

DIATOM Any of a class of minute planktonic unicellular or colonial algae with silicified skeletons.

DIOXIN A group of approximately 75 chemicals of the chlorinated dibenzodioxin family, including 2, 3, 7, 8 - tetrachlorodibenzo-para-dioxin (2,3,7,8 - TCDD) which is generally considered the most toxic form.

DISSOLVED OXYGEN The amount of oxygen dissolved in water.

DRAINAGE BASIN A waterway and the land area drained by it.

DREDGE SPOILS The material removed from the river, lake, or harbour bottom during dredging operations.

DREDGING GUIDELINES Procedural directions designed to minimize the adverse effects of shoreline and underwater excavation with primary emphasis on the concentrations of toxic materials within the dredge spoils.

ECOSYSTEM The interacting complex of living organisms and their non-living environment; the biotic community and its abiotic environment.

EFFLUENT Contaminated waters discharged from facilities to either wastewater sewers or to surface waters.

ENVIRONMENT All the biotic and abiotic factors that actually affect an individual organism at any point in its life cycle.

EPHEMERAL A plant that grows, flowers, and dies in a few days.

EPHEMERA Invertebrates (mayflies) that live as adults only a very short time.

EPILIMNION The warm, upper layer of water in a lake that occurs during summer stratification.

EROSION The wearing away and transportation of soils, rocks and dissolved minerals from the land surface, shorelines, or river bottom by rainfall, running water, wave and current action.

EUTROPHICATION The process of nutrient enrichment that causes high productivity and biomass in an aquatic ecosystem. Eutrophication can be a natural process so it can be a cultural process accelerated by an increase of nutrient loading to a waterbody by human activity.

EXOTIC SPECIES Species that are not native to the Great Lakes and have been intentionally or inadvertently inroduced into the system.

FACULTATIVE Exhibiting a broad lifestyle which allows it to survive under a broad range of environmental conditions.

FOODCHAIN The process by which organisms in higher trophic levels gain energy by consuming organisms at lower trophic levels; the dependence for food of organisms upon others in a series, beginning with plants and ending with the largest carnivores.

GOAL An aim or objective towards which to strive; it may represent an ideal condition that is difficult, if not impossible to attain economically.

GREAT LAKES BASIN ECOSYSTEM The interacting components of air, land, water and living organisms, including man, within the drainage basin of the St. Lawrence River at or upstream from the point at which this river becomes the international boundary between Canada and the United States (from Article 1 of the 1978 GLWQ Agreement).

GREAT LAKES WATER QUALITY AGREEMENT (GLWQA) A joint agreement between Canada and the United States which commits the two countries to develop and implement a plan to restore and maintain the many desirable uses of the waters in the Great Lakes Basin. Originally signed in 1972, the Agreement was amended in 1978 and 1987.

GROUNDWATER Water entrained and flowing below the surface which may supply water to wells and springs.

GUIDELINES Any suggestion or rule that guides or directs; i.e. suggested criteria for programs or effluent limitations.

HALF-LIFE The period of time in which a substance loses half of its active characteristics (used specifically in radiological work); the amount of time required for the concentration of a pollutant to decrease to half of the original value through natural decay or decomposition.

HAZARDOUS SUBSTANCES Chemicals considered to be a threat to man in the environment, including substances which (individually or in combination with other substances) can cause death, disease (including cancer), behavioural abnormalities, genetic mutations, physiological malfunctions or physical deformities.

HYDROLOGIC CYCLE The natural cycle of water on earth, including precipitation as rain and snow, runoff from land, storage in groundwaters, lakes, streams, and oceans, and evaporation and transpiration (from plants) into the atmosphere to complete the cycle.

HYPOLIMNION The cold, dense, lower layer of water in a lake that occurs during summer stratification.

ICHTHYOLOGY A branch of zoology that deals with fishes.

INCIPIENT LC_{50} The level of the toxicant which is lethal for 50% of individuals exposed for periods sufficiently long that acute lethal action has ceased. Synonymous with lethal threshold concentration.

INCIPIENT LETHAL LEVEL That concentration of a contaminant beyond which an organism could no longer survive for an indefinite period of time.

INSECTICIDE Substances or a mixture of substances intended to prevent, destroy or repel insects.

LACUSTRINE Formed in, or growing in lakes.

LEACHATE Materials dissolved or suspended in water that percolate through solids such as soils, solid wastes and rock layers.

LETHAL Involving a stimulus or effect directly causing death.

LIPOPHILIC Having an affinity for fats or other lipids.

LITTORAL Productive shallow water zone of lakes, rivers or the seas, with light penetration to the bottom; often occupied by rooted aquatic plants.

LOADINGS Total mass of pollutant to a water body over a specified time; e.g. tonnes per year of phosphorus.

MACROPHYTE A member of the macroscopic plant life (i.e. larger than algae) especially of a body of water.

MACROZOOBENTHOS The distribution of macrozoobenthos in an aquatic ecosystem is often used as an index of the impacts of contamination on the system.

MALIGNANT Resistent to treatment, occurring in severe form and frequently fatal.

MASS BALANCE An approach to evaluating the sources, transport and fate of contaminants entering a water system, as well as their effects on water quality. In a mass balance budget, the amounts of a contaminant entering the system less the amount leaving the system. If inputs exceed outputs, pollutants are accumulating and contaminant levels are rising. Once a mass balance budget has been established for a pollutant of concern, the long-term effects on water quality can be simulated by mathematical modelling and priorities can be set for research and remedial action.

MUTAGEN Any substance or effect which alters genetic characteristics or produces an inheritable change in the genetic material.

MUTAGENICITY The ability of a substance to induce a detectable change in genetic material which can be transmitted to progeny, or from one cell generation to another within an individual.

NONPOINT SOURCE Source of pollution in which pollutants are discharged over a widespread area or from a number of small inputs rather than from distinct, identifiable sources.

NUTRIENT A chemical that is an essential raw material for the growth and development of organisms.

ORGANOCHLORINE Chlorinated hydrocarbon pesticides.

PATHOGEN A disease causing agent such as bacteria, viruses, and parasites.

PERIPHYTON Organisms that live attached to underwater surfaces.

PERSISTENT TOXIC SUBSTANCES Any toxic substance with a half-life in water and greater than eight weeks.

PESTICIDE Any substance used to kill plants, insects, algae, fungi or other organisms; includes herbicides, insecticides, algicides, fungicides.

PHENOLICS Any of a number of compounds with the basic structure of phenol but with substitutions made onto this structure. Phenolics are produced during the coking of coal, the distillation of wood, the operation of gas works and oil refineries, from human and animal wastes, and the microbiological decomposition of organic matter.

PHOTOSYNTHESIS A process occurring in the cells of green plants and some micro-organisms in which solar energy is transformed into stored chemical energy.

PHYTOPHAGOUS Feeding on plants.

PHYTOPLANKTON Minute, microscopic aquatic vegetative life; plant portion of the plankton; the plant community in marine and freshwater situations which floats free in the water and contains many species of algae and diatoms.

POINT SOURCE A source of pollution that is distinct and identifiable, such as an outfall pipe from an industrial plant.

POLLUTION (WATER) Anything causing or inducing objectionable conditions in any watercourse and affecting adversely the environment and use or uses to which the water thereof may be put.

POTABLE WATER Water suitable, on the basis of both health and aesthetic considerations, for drinking or cooking purposes.

PRECAMBRIAN The earliest era of geological history.

PRIMARY TREATMENT Mechanical removal of floating or settable solids from wastewater.

PUBLIC Any person, group, or organization.

RADIONUCLIDE A radioactive material.

RAPTORS Birds of prey.

RAW WATER Surface or groundwater that is available as a source of drinking water, but has not received any treatment.

RESUSPENSION (of sediment) The remixing of sediment particles and pollutants back into the water by storms, currents, organisms and human activities such as dredging.

RIPARIAN Living or located on the bank of a natural watercourse.

SCAUP A diving duck.

SECONDARY TREATMENT Primary treatment plus bacterial action to remove organic parts of the waste.

SEDIMENT The fines or soils on the bottom of the river or lake.

SEICHE An oscillation in water level from one end of a lake to another due to wind or atmospheric pressure. Most dramatic after an intense but local weather disturbance passes over one end of a large lake.

SELENIUM A nonmetallic element that chemically resembles sulfur and is obtained chiefly as a by-product in copper refining, and occurs in allotropic forms of which a gray stable form varies in electrical conductivity with the intensity of its illumination and is used in electronic devices.

SESSILE An animal that is attached to an object or is fixed in place (e.g. barnacles).

SIGMOID CURVE S-shaped curve (e.g. the logistic curve)

SLUDGE The solids removed from waste treatment facilities.

SOLUBILITY Capability of being dissolved.

STABILITY Absence of fluctuations in populations; ability to withstand perturbations without large changes in composition.

STRATIFICATION (or layering) The tendency in deep lakes for distinct layers of water to form as a result of vertical change in temperature and therefore, in the density of water.

SUBACUTE Involving a stimulus below the level that causes death.

SUBCHRONIC Effects from short-term multiple dosage or exposure; usually means exposure for less than three months.

SUB-LETHAL Involving a stimulus below the level that causes death.

SUSPENDED SEDIMENTS Particulate matter suspended in water.

SYNERGISM The joint action of two or more substances is greater than the sum of the action of each of the individual substances. The improvement in performance is achieved because two agents are working together. See also Antagonism.

SYNERGISTIC Interactions of two or more substances or organisms producing a result such that the total effect is greater than the sum of the individual effects.

SYNTHESIS The production of a substance by the union of elements or simpler compounds.

TAXA A group of similar organisms.

TAXONOMICALLY To identify an organism by its structure.

TERATOGEN A substance that increases the incidence of birth defects.

TERATOGENICITY The ability of a substance to produce irreversible birth defects, or anatomical or functional disorders as a result of an effect on the developing embryo.

THERMOCLINE A layer of water in lakes separating cool hypolimnion (lower layer) from the warm epilimnion (surface layer).

THRESHOLD The chemical concentration or dose that must be reached before a given reaction occurs.

TOXIC SUBSTANCE As defined in the Great Lakes Agreement, and substance that adversely affects the health or well being of any living organism.

TOXICITY Quality, state or degree of the harmful effect resulting from alteration of an environmental factor.

TRANSLOCATION Movement of chemicals within a plant or animal; usually refers to systemic herbicides and insecticides that are moved from the point of contact on the plant to other regions of the plant.

TROPHIC ACCUMULATION Passing of a substance through a food chain such that each organism retains all or a portion of the amount in its food and eventually acquires a higher concentration in its flesh than in its food. See also Biological Magnification.

TROPHIC LEVEL Functional classification of organisms in a community according to feeding relationships; the first trophic level includes green plants, the second level includes herbivores; etc.

TROPHIC STATUS A measure of the biological productivity in a body of water. Aquatic ecosystems are characterized as oligotrophic (low productivity), mesotrophic (medium productivity) or eutrophic (high productivity).

TUBIFICID Of aquatic oligochaete or sludge worms which is tolerant to organically enriched waters.

TURBIDITY Deficient in clarity of water.

WATER QUALITY OBJECTIVES Under the Great Lakes Water Quality Agreement, goals set by the Governments of the United States Agreement, goals set by the Governments of the United States and Canada for protection of the uses of the Great Lakes.

WATER QUALITY STANDARD A criterion or objective for a specific water use standard that is incorporated into enforceable regulations.

WIND SET-UP A local rise in water levels caused by winds pushing water to one side of a lake. (See Seiche)

ppm? ppb? ppt?

"Parts per million", "parts per billion", and even "parts per trillion" have gradually worked their way into commonly accepted usage as expressions of air and water pollutant measurements. But who, other than the experts, really knows what these terms mean? What are the terms of reference? How small is small?

Research chemists recently undertook the challenge of delineating some readily understandable terms of reference. The assignment clearly sparked the group's collective imagination, as the list of comparisons they produced shows.

One part per million:
= one inch in 16 miles;
= one minute in two years;
= one ounce in 31 tons of potato chips;
= one bad apple in 2,000 barrels.

One part per billion:
= one inch in 16,000 miles;
= one second in 32 years;
= a pinch of salt in 10 tons of potato chips;
= one bad apple in 2 million barrels.

One part per trillion:
= one hairsbreadth (blond specified) in a trip around the world;
= one second in 320 centuries;
= a pinch of salt in 10,000 tons of potato chips;
= a drop of vermouth in 250,000 hogsheads of gin; or, getting even more specific;
= one flea in 360 million elephants.

At what point are chemicals perceived? Table salt in water becomes somewhat unpalatable at one part per thousand; swimmers can detect chlorine in a pool at one part per million; and sensitive noses can detect the odour of fuel oil at one part per billion. One part per trillion of anything is not detectable without the use of advanced and costly analytical equipment.

Appendicies

St. Marys River Remedial Action Plan

Appendix 2.1

Guidelines For Recommending The Listing and Delisting of Great Lakes Areas of Concern

Appendix 2.1 Guidelines for Recommending the Listing and Delisting of Great Lakes Areas of Concern

USE IMPAIRMENT	LISTING GUIDELINE	DELISTING GUIDELINE	RATIONALE	REFERENCE
RESTRICTIONS ON FISH AND WILDLIFE CONSUMPTION	When contaminant levels in fish or wildlife populations exceed current standards, objectives or guidelines, or public health advisories are in effect for human consumption of fish or wildlife. Contaminant levels in fish and wildlife must be due to contaminant input from the watershed.	When contaminant levels in fish and wildlife populations do not exceed current standards, objectives or guidelines, and no public health advisories are in effect for human consumption of fish or wildlife. Contaminant levels in fish and wildlife must be due to contaminant input from the watershed.	Accounts for jurisdictional and federal standards; emphasizes local watershed sources.	Adapted from Mack 1988
TAINTING OF FISH AND WILDLIFE FLAVOR	When ambient water quality standards, objectives, or guidelines, for the anthropogenic substance(s) known to cause tainting, are being exceeded or survey results have identified tainting of fish or wildlife flavor.	When survey results confirm no tainting of fish or wildlife flavor.	Sensitive to ambient water quality standards for tainting substances; emphasizes survey results.	See American Public Health Association (1980) for survey methods
DEGRADED FISH AND WILDLIFE POPULATIONS	When fish and wildlife management programs have identified degraded fish or wildlife populations due to a cause within the watershed. In addition, this use will be considered impaired when relevant, field-validated, fish or wildlife bioassays with appropriate quality assurance/quality controls confirm significant toxicity from water column or sediment contaminants.	When environmental conditions support healthy, self-sustaining communities of desired fish and wildlife at predetermined levels of abundance that would be expected from the amount and quality of suitable physical, chemical and biological habitat present. An effort must be made to ensure that fish and wildlife objectives for Areas of Concern are consistent with Great Lakes ecosystem objectives and Great Lakes Fishery Commission fish community goals. Further, in the absence of community structure data, this use will be considered restored when fish and wildlife bioassays confirm no significant toxicity from water column or sediment contaminants.	Emphasizes fish and wildlife management program goals; consistent with Agreement and Great Lakes Fishery Commission goals; accounts for toxicity bioassays.	Adapted from Manny and Pacific, 1988. Wisconsin DNR 1987 United States and Canada, 1987; Great Lakes Fishery Commission 1980
FISH TUMORS OR OTHER DEFORMITIES	When the incidence rates of fish tumors or other deformities exceed rates at unimpacted control sites or when survey data confirm the presence of neoplastic or preneoplastic liver tumors in bullheads or suckers.	When the incidence rates of fish tumors or other deformities do not exceed rates at unimpacted control sites and when survey data confirm the absence of neoplastic or preneoplastic liver tumors in bullheads or suckers.	Consistent with expert opinion on tumors; acknowledges background incidence rates.	Adapted from Mac and Smith, 1988; Black 1983; Baumann et al. 1982
BIRD OR ANIMAL DEFORMITIES OR REPRODUCTIVE PROBLEMS	When wildlife survey data confirm the presence of deformities (e.g. cross-bill syndrome) or other reproductive problems (e.g. egg-shell thinning) in sentinel wildlife species.	When the incidence rates of deformities (e.g. cross bill syndrome) or reproductive problems (e.g. egg-shell thinning) in sentinel wildlife species do not exceed background levels in inland control populations.	Emphasizes confirmation through survey data; makes necessary control comparisons.	Adapted from Kubiak 1988; Miller 1988. Wiemeyer et al. 1984
DEGRADATION OF BENTHOS	When the benthic macroinvertebrate community structure significantly diverges from unimpacted control sites of comparable physical and chemical characteristics. In addition, this use will be considered impaired when toxicity (as defined by relevant, field-validated, bioassays with appropriate quality assurance/quality controls) of sediment-associated contaminants at a site is significantly higher than controls.	When the benthic macroinvertebrate community structure does not significantly diverge from unimpacted control sites of comparable physical and chemical characteristics. Further, in the absence of community structure data, this use will be considered restored when toxicity of sediment-associated contaminants is not significantly higher than controls.	Accounts for community structure and composition; recognizes sediment toxicity; uses appropriate control sites.	Adapted from Reynoldson 1988. Henry 1988; IJC 1988

Appendix 2.1 (Cont'd)

USE IMPAIRMENT	LISTING GUIDELINE	DELISTING GUIDELINE	RATIONALE	REFERENCE
RESTRICTIONS ON DREDGING ACTIVITIES	When contaminants in sediments exceed standards, criteria, or guidelines such that there are restrictions on dredging or disposal activities.	When contaminants in sediments do not exceed standards, criteria, or guidelines such that there are restrictions on dredging or disposal activities.	Accounts for jurisdictional and federal standards; emphasizes dredging and disposal activities.	Adapted from IJC 1988
EUTROPHICATION OR UNDESIRABLE ALGAE	When there are persistent water quality problems (e.g. dissolved oxygen depletion of bottom waters, nuisance algal blooms or accumulation, decreased water clarity, etc.) attributed to cultural eutrophication.	When there are no persistent water quality problems (e.g. dissolved oxygen depletion of bottom waters, nuisance algal blooms or accumulation decreased water clarity, etc.) attributed to cultural eutrophication.	Consistent with Annex 3 of the Agreement; accounts for persistence of problems.	United States and Canada, 1987
RESTRICTIONS ON DRINKING WATER CONSUMPTION OR TASTE AND ODOR PROBLEMS	When treated drinking water supplies are impacted to the extent that: 1) densities of disease-causing organisms or concentrations of hazardous or toxic chemicals or radioactive substances exceed human health standards, objectives or guidelines; 2) taste and odor problems are present; or 3) treatment needed to make raw water suitable for drinking is beyond the standard treatment used in comparable portions of the Great Lakes which are not degraded (i.e. settling, coagulation, disinfection).	For treated drinking water supplies: 1) when densities of disease-causing organisms or concentrations of hazardous or toxic chemicals or radioactive substances do not exceed human health objectives, standards or guidelines; 2) when taste and odor problems are absent; and 3) when treatment needed to make raw water suitable for drinking does not exceed the standard treatment used in comparable portions of the Great Lakes which are not degraded (i.e. settling, coagulation, disinfection).	Consistency with the Agreement; accounts for jurisdictional standards; practical; sensitive to increased cost as a measure of impairment.	Adapted from United States and Canada, 1987
BEACH CLOSINGS	When waters, which are commonly used for total-body contact or partial-body contact recreation, exceed standards, objectives, or guidelines for such use.	When waters, which are commonly used for total-body contact or partial-body contact recreation, do not exceed standards, objectives, or guidelines for such use.	Accounts for use of waters; sensitive to jurisdictional standards; addresses water contact recreation; consistent with the Agreement.	Adapted from United States and Canada, 1987; Ontario Ministry of the Environment 1984
DEGRADATION OF AESTHETICS	When any substance in water produces a persistent objectionable deposit, unnatural color or turbidity, or unnatural odor (e.g. oil slick, surface scum).	When the waters are devoid of any substance which produces a persistent objectionable deposit, unnatural color or turbidity, or unnatural odor (e.g. oil slick, surface scum).	Emphasizes aesthetics in water; accounts for persistence.	Adapted from the Ontario Ministry of the Environment 1984
ADDED COSTS TO AGRICULTURE OR INDUSTRY	When there are additional costs required to treat the water prior to use for agricultural purposes (i.e. including, but not limited to, livestock watering, irrigation and crop-spraying) or industrial purposes (i.e. intended for commercial or industrial applications and noncontact food processing).	When there are no additional costs required to treat the water prior to use for agricultural purposes (i.e. including, but not limited to, livestock watering, irrigation and crop-spraying) and industrial purposes (i.e. intended for commercial or industrial applications and noncontact food processing).	Sensitive to increased cost and a measure of impairment.	Adapted from Michigan DNR 1977
DEGRADATION OF PHYTOPLANKTON AND ZOOPLANKTON POPULATIONS	When phytoplankton or zooplankton community structure significantly diverges from unimpacted control sites of comparable physical and chemical characteristics. In addition, this use will be considered impaired when relevant, field-validated, phytoplankton or zooplankton bioassays (e.g. Ceriodaphnia; algal fractionation bioassays) with appropriate quality assurance/quality controls confirm toxicity in ambient waters.	When phytoplankton and zooplankton community structure does not significantly diverge from unimpacted control sites of comparable physical and chemical characteristics. Further, in the absence of community structure data, this use will be considered restored when phytoplankton and zooplankton bioassays confirm no significant toxicity in ambient waters.	Accounts for community structure and composition; recognizes water column toxicity; uses appropriate control sites.	Adapted from IJC 1987
LOSS OF FISH AND WILDLIFE HABITAT	When fish and wildlife management goals have not been met as a result of loss of fish and wildlife habitat due to a perturbation in the physical, chemical, or biological integrity of the Boundary Waters, including wetlands.	When the amount and quality of physical, chemical, and biological habitat required to meet fish and wildlife management goals have been achieved and protected.	Emphasizes fish and wildlife management program goals; emphasizes water component of Boundary Waters.	Adapted from Manny and Pacific, 1988

Appendix 3.1

St. Marys River Remdial Action Plan (RAP) Team Members

Appendix 3.1 St. Marys River Remedial Action Plan (RAP) Team Members

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Appendix 3.1 (Cont'd)

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Appendix 3.2

St. Marys River Remedial Action Plan Reference Centres and Example Newsletter

Appendix 3.2 St. Marys River Remedial Action Plan Reference Centres

Local libraries have agreed to serve as reference centres for the St. Marys River Remedial Action Plan. Throughout the RAP process, copies of reports and other material will be placed for reference use at the following locations:

<u>ONTARIO</u>

Algoma University Library
1520 Queen Street East
SAULT STE. MARIE, Ontario
P6A 2G3

City Library - Main Branch
50 East Street
SAULT STE. MARIE, Ontario
P6A 3C3

Environment Ontario
445 Albert Street
SAULT STE. MARIE, Ontario
P6A 2J9

Sault College
443 Northern Avenue
SAULT STE. MARIE, Ontario
P6A 5L3

<u>MICHIGAN</u>

Lake Superior State University Library
1000 College Drive
SAULT STE. MARIE, Michigan 49783

Bayliss Public Library
541 Library Drive
SAULT STE. MARIE, Michigan 49783

NUMBER 1 • WINTER • 1988

ST. MARYS RIVER REMEDIAL ACTION PLAN

Community plan for river cleanup underway

Dear Reader:

The St. Marys River is an important fish spawning area, a tourist recreation attraction, and it provides drinking and industrial process water. However, the water is polluted as a result of the many uses it has been put to and has been identified as one of 42 areas of concern in the Great Lakes Basin requiring the preparation of a Remedial Action Plan (RAP).

Being a shared waterway between Michigan and Ontario, a cooperative effort has been initiated. Development of one international plan by the RAP team is anticipated to take two years.

This team is composed of scientists from Environment Ontario, Environment Canada, the Ministry of Natural Resources, and the Michigan Department of Natural Resources. This team will compile the environmental data base, coordinate the unity of the plan, and ensure public involvement in the planning process.

Through an effective public involvement program, local communities will be involved in setting goals, program development, implementation and evaluation.

By acknowledging our joint responsibility today, residents and visitors can enjoy the benefits offered by improved water quality in the future. Please join the effort!

Yours truly,
St. Marys River RAP Coordinating Team

Wayne Wager

Wayne C. Wager
Canadian Coordinator

Diana Klemans

Diana Klemans
U.S. Coordinator

Remedial Action Plan
Plan d'Assainissement

Canada Ontario DNR

Wayne Wager addresses an enthusiastic group of BPAC members and an unexpected number of interested observers

BPAC has first meeting

To write a plan which reflects the concerns of the public, a citizens' group made up of people from Canada and the United States, called the Binational Public Advisory Council (BPAC), has been established.

The BPAC will comment to and advise the RAP Team on key aspects of the remedial action plan preparation and implementation. This includes the goals of the plan, problems to be addressed, and plan implementation. The goal is to arrive at a plan for which there is a concensus.

Thirty-seven members and twelve alternates have agreed to serve on the BPAC. There were approximately 50 nominations.

At its first meeting on November 3rd, the BPAC adopted its charge and developed meeting procedures. There was good discussion among the BPAC membership about the planning process, and their role in developing the St. Marys River RAP.

Members of the RAP Team were in attendance and there were many observers, including reporters from the local media.

The next BPAC meeting will be January 12, 1989 from 7:00-9:00 pm at the Walker Cisler Center, Lake Superior State University in Sault Ste. Marie, Michigan.

Guest Forum

By Fraser Craig, Environmental Control Supervisor, Algoma Steel Corporation

(The following is a portion of a statement presented at the public information sessions held on February 10, 1988.)

Algoma Steel is a major stakeholder on the St. Marys River through the company's steelworks on the Canadian side of the river and through property owned on the Michigan side. I would like to make it very clear that Algoma will cooperate with the RAP Team in its efforts to maintain and improve the water quality of the St. Marys River.

Algoma has had a Control Order for many years which has resulted in the reduction of conventional pollutants to their current levels. Cyanide in the terminal basin effluent, for example, is 97% lower than levels in the mid 1970's. Ammonia is 80% lower over the same time period.

The Ministry's tight effluent standards require additional equipment which will further improve the quality of Algoma's water discharges. These improvements will take place between 1988 and 1990 at a cost to Algoma in excess of $25 million. Also, as new production units have been added to the Corporation these facilities come equipped with the latest technology available for air and water waste treatment.

Algoma is an active participant in the Municipal Industrial Strategy for Abatement (MISA) program through the Canadian Steel Environmental Association. MISA is an MOE initiative to eliminate persistent organics from water discharges in the province.

The Ministry plans to complete a study on the Algoma slag site to determine if there are environmental problems. This study will take place over the next 18 to 24 months, and Algoma will cooperate with the Ministry and its consultant. Algoma sees the most immediate answer as the recycling of waste material as it is produced. We are, in fact, disposing of two different commodities by recycling at present. In other areas we are actively pursuing technology that will allow us to reuse these wastes as a product or produce a saleable by-product.

We should not forget that the St. Marys River is not a "dead" river, but rather a vital and healthy resource. It is a source of fish, a focal point for tourists and provides fresh water for the general population and for industry. We at Algoma would like to assist in keeping it that way.

The steel industry in general, and Algoma in particular, is faced with the reality of shrinking markets and keen competition from offshore producers, however, at the same time Algoma recognizes the problems and accepts the environmental challenges of the 1980's. As a responsible corporate citizen Algoma will work towards practical and acceptable solutions for all sides.

By Congressman Davis, State of Michigan

(This is a portion of the statement presented by Bill Huber on behalf of Congressman Davis at the February 10, 1988 public information sessions.)

The St. Marys River deserves our special attention, as it has been identified as one of the 42 most polluted areas in the Great Lakes by the International Joint Commission. In addition, because the St. Marys River serves as a narrow stream of international water, both U.S. and Canadian laws and our goodwill will be tested to see if we can meet the stringent goals of the Great Lakes Water Quality Agreement.

Last December, I sent representatives to visit the Sault Ste. Marie area, to hear the concerns of those who live along the River, who draw their drinking water from the River, and who fish the rapids. They learned that the people were concerned about current industrial waste disposal practices, dredging in the water, and the effects this has on humans, fish and wildlife in the area.

We realize that a solution to cleaning up these polluted waters and sediments lining the River bottom will take some time: after all, it took years for the River to become polluted. However, it is important that we look to the future and ensure that water quality of the River will improve.

To this end, I am encouraged that the Government of Ontario has recently approved funds for an extensive monitoring program along the Algoma Steel site. In addition, Algoma Steel has been altering its waste treatment practices to ensure that additional organic chemicals do not accidentally leach into the River. I have pledged to make sure that the U.S. upholds its role in rehabilitating the River and will seek funding, and new legislation if necessary, to achieve the goals developed in this Remedial Action Plan.

The Ministry of Environment and the Michigan Department of Natural Resources should be applauded for initiating a Public Involvement Program so early in the planning process. No one knows better what types of problems the River is experiencing and what the goals of the RAP should be than those who see and use the St. Marys River every day. The Remedial Action Plan resulting from this planning process is really the only mechanism by which both the United States and Canada can ensure that the waters of the St. Marys River will be improved and maintained.

Do you have an opinion on issues related to the St. Marys River RAP?

Share your concerns in the next newsletter by writing to the RAP Team. Your letter may be part of our regular opinion column. Share your thoughts about planning for the St. Marys River with other interested people.

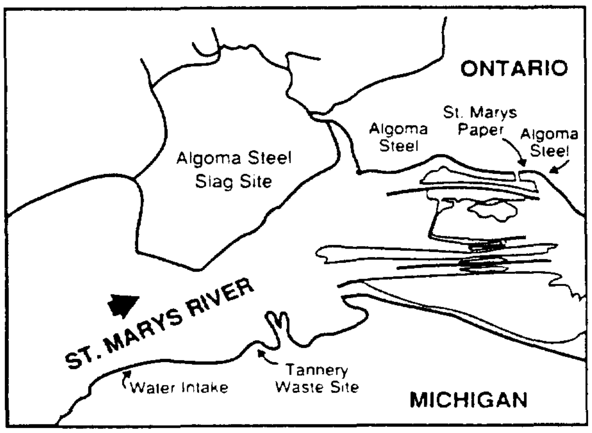
Address your letters to the: St. Marys River RAP
Environment Ontario
265 Front Street North
Suite 109
Sarnia, Ontario N7T 7X1

Profile: Slag?

A 400 hectare (1000 acre) slag site owned by the Algoma Steel Corporation is a source of concern for many residents along the St. Marys River. The site was partially created by infilling portions of the river. Up until 1978, Algoma dyked off a portion of a water lot to be used as a slag disposal site. Since 1978 further expansion into the river for slag disposal has not been approved.

Many people have asked, "What is slag? Can we use it to build a playground? What does it do to the river?"

In general terms, slag is the unwanted molten rock residue remaining after the useful iron is



removed from the ore. The impurities in the slag are mostly metals, and oxides of metals, inorganic compounds formed in the complex reactions which occur in the thermal reduction process of steel making. Few organic chemicals could survive the high process temperatures of over 1500 C (2800 F), without converting to their elemental form, mostly carbon, hydrogen, and oxygen.

The inorganic components of slag may include carbonates of calcium and magnesium, calcium oxide, silicon dioxide, sulfide, aluminium, maganese, magnesium and iron depending upon their presence in the iron ore. The element which causes the greatest impact on the aquatic environment is also the largest component of slag, calcium carbonate (or limestone). When placed in water, the slag may cause a significant rise in pH and buffering capacity.

Slag produced by removing the impurities of the ore is called blast furnace (BF) slag. The iron is then refined into steel which produces steel slag. Both BF and steel slags are used as aggregate material for roads, driveways and parking areas in the Sault area. The use of slag as fill and construction material, and the presence of the slag disposal site raise two important questions:

Will the chemical compounds of the slag leach into the St. Marys River? If so, will this result in harmful or toxic effects?

Studies have found that leachate, dissolved material which percolates through soils, occurs in direct proportion to the amount of surface area exposed to water. Steel slag protects itself from leaching once a calcium carbonate layer forms on its surface. After a short period of time BF slag will cease leaching, but a calcium carbonate layer does not form.

Concerns expressed about the slag site are motivated not only by concerns for leachates from the slag, but also from other waste disposed at the site.

An investigation of the conductivity of the St. Marys River sediments adjacent to the Algoma slag site was undertaken by Environment Ontario. Contaminated groundwater generally has a higher electrical conductance than uncontaminated groundwater. Thus, measurement of electrical conductance is useful in determining potential zones of groundwater contamination. This study has shown six areas where contaminated shallow groundwater at the shoreline of the site may be discharging into the St. Marys River. Four of these six sites correspond with the location of elevated heavy metals, oil and grease. PCBs and PAHs have been detected in sediments or biota.

Further studies have been initiated. One such study, recently commissioned by Environment Ontario, is a hydrogeological and surface runoff investigation of the slag site over the next two years. The purpose of the study is to determine if contaminants are leaching or running off the site and affecting the river.

Findings of the investigations on and near the Algoma Steel slag site include:

- PAHs were found in the surface water of the St. Marys River, the Algoma boat slip, and East Davignon Creek Gate No. 4.
- Surface drainage at the slag site seems minimal.
- Groundwater appears to be flowing from the Algoma slag site towards the St. Marys River, thus the potential for the discharge of contaminants to the river seems to be high. Goundwater may also be moving locally from the slag site towards the Steelton and Goulais water supply wells. At this time, it is not possible to confirm whether or not this water could impact wells.
- PAHs and cyanide were found in the overburden and bedrock in the area of the slag site.
- Tar-like materials were found in the bottom of Spring and Bennett Creeks.

RAP highlights 1988

February 10th

Close to 200 citizens attended the afternoon and evening public information sessions held in Sault Ste. Marie, Ontario and Michigan. Many questions focusing on the health of the river were asked. At these meetings, the formation of the Binational Public Advisory Council (BPAC) was proposed.

March and April

The RAP Coordinators attended local trade and sports shows to answer the public's questions about the RAP and to encourage their involvement. Close to 200 people expressed interest over two different weekends.

June 16th

Approximately 80 people attended a public meeting in Sault Ste. Marie, Ontario. Fish advisories and point sources were discussed. As well, a call for nominations to the citizens' group called the BPAC was made. Fifty nominations for 37 seats were received over the summer.

November 3rd

The first BPAC meeting was held in Sault Ste. Marie, Ontario. The next BPAC meeting will be January 12, 1989.

The next public meeting is scheduled for the Spring, 1989.

To Contact the St. Marys River RAP Team:

In Ontario write:

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Coordinator
Environment Ontario
265 Front Street North
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Sarnia, Ontario
N7T 7X1

In Michigan write:

Diana Klemans
Coordinator
Michigan Department of Natural Resources
Surface Water Quality Division
P.O. Box 30028
Lansing, MI 48909

RAP-Line:

In Ontario:
(Area Codes 705, 519 and 416 only)

1-800-265-0248

In Michigan:

1-517-373-2758

Reference Centres have been established in local libraries in which we will be placing various reports for your convenience:

Ontario:

Algoma University Library
1520 Queen Street E.
Sault Ste. Marie, Ontario

City Library - Main Branch
50 East Street
Sault Ste. Marie, Ontario

Sault College
443 Northern Avenue
Sault Ste. Marie, Ontario

Environment Ontario
445 Albert Street
Sault Ste. Marie, Ontario

Michigan:

Lake Superior State University
1000 College Drive
Sault Ste. Marie, MI

Bayliss Public Library
541 Library Drive
Sault Ste. Marie, MI

Appendix 3.3

St. Marys River Binational Public Advisory Council (BPAC) Meeting Dates and Locations

Appendix 3.3 St. Marys River Binational Public Advisory Council (BPAC) Meeting Dates and Locations

Date	Place
Canada	
November 3, 1988	Holiday Inn
February 22, 1989	Holiday Inn
May 2, 1989	Holiday Inn
July 6, 1989	Holiday Inn
September 12, 1989	Ramada Inn
September 28, 1989	Ramada Inn
November 28, 1989	Holiday Inn
January 11, 1990	Holiday Inn
February 28, 1990	Garden River First Nation Fire Hall
May 2, 1990	Holiday Inn
July 11, 1990	Holiday Inn
August 21, 1990	Marconi Hall
September 19, 1990	Holiday Inn
November 14, 1990	Holiday Inn
January 10, 1991	Holiday Inn
March 14, 1991	Holiday Inn
May 22, 1991	Holiday Inn
United States	
January 12, 1989	Lake Superior State University (LSSU)
April 3, 1989	LSSU
June 8, 1989	Ramada Inn
August 14, 1989	LSSU
October 28, 1989	LSSU
January 30, 1990	LSSU
March 27, 1990	LSSU
June 7, 1990	LSSU
August 14, 1990	LSSU
October 18, 1990	LSSU
December 11, 1990	LSSU
February 13, 1991	LSSU
April 23, 1991	LSSU

Appendix 3.4

St. Marys River Binational Public Advisory Council (BPAC) Members and Alternates

Appendix 3.4 St. Marys River Binational Public Advisory Council (BPAC), May 31, 1991: Members (M) and Alternates (A)

ACADEMIA

ONTARIO

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MICHIGAN

NR (No Representative)

FISHERIES

ONTARIO

NR

MICHIGAN

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Ms. Catherine Fraser (A)
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Mr. A. Dave Stewart (M)
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Captain F. Manzzutti (M)
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MICHIGAN

NR

LABOUR

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MICHIGAN

NR

RECREATION/TOURISM

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Appendix 3.4 (Cont'd)

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Appendix 3.4 (Cont'd)

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Mr. Steve Gipp (M)
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Appendix 3.4 (Cont'd)

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Appendix 3.4 (Cont'd)

ELECTED OFFICIALS

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Mr. Tony Martin, MPP (M)
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NR

Appendix 4.1

Legislation Cited In Chapter 4

Appendix 4.1 Legislation Cited in Chapter 4

Ontario Legislation

Ontario Water Resources Act
Ontario Environmental Protection Act
Pesticides Act, 1980
Environmental Assessment Act
Dangerous Goods Transportation Act
Drainage Act Public Lands Act
Fisheries Act Dangerous Goods Act
Planning Act

Canadian Legislation

Food and Drug Act
Canadian Constitution Act of 1867
Fisheries Act
Canada Water Act
Canadian Environmental Protection Act
Canada Shipping Act
Transport of Dangerous Goods Act
Pest Control Products Act
Canadian Clean Air Act
Environmental Contaminants Act (repealed)

Michigan Acts

Michigan Water Resources Commission Act, 1929 PA 245, as amended
- Part 4 - Water Quality Standards
- Part 5 - Spillage of Oil and Polluting Materials

Soil Erosion and Sedimentation Control Act, 1972 PA 347
Oil and Gas Act, PA 61
Solid Waste Management Act, 1978 PA 641
Michigan Environmental Response Act, 1982 PA 307
Hazardous Waste Management Act, 1979 PA 64, as amended
Michigan Pesticide Control Act, 1976 PA 171
Michigan Air Pollution Act, 1965 PA 348
Michigan Safe Drinking Water Act, 1976 PA 399
Goemaere - Anderson Wetland Protection Act, 1979 PA 203
Inland Lakes and Streams Act, 1972 PA 346
Great Lakes Submerged Lands Act, 1955 PA 247
Michigan Environmental Protection Act, 1970 PA 127
Shoreline Protection and Management Act, 1970 PA 245
Natural Rivers Act, 1970 PA 231
Subdivision Control Act, 1968 PA 288
Administrative Procedures Act, 1969 PA 306
Toxic Substances Control Act, 1978 PA 116

Appendix 4.1 (Cont'd)

United States Public Laws

Federal Water Pollution Control Act, 1972 PL 92-500, as amended (Clean Water Act)
Comprehensive Environmental Response, Compensation and Liability Act, 1980 PL 96-510 (CERLCA)
Solid Waste Disposal Act
Emergency Planning and Community Right-to-Know Act, 1986
Toxic Substances Control Act
Non-Indigenous Aquatic Nuisance Act - Proposed Senate Bill
Aquatic Nuisance Prevention and Control Act - Proposed House Bill
Resource Conservation and Recovery Act, PL 94-586 (RCRA)
Federal Insecticide, Fungicide and Rodenticide Act Clean Air Act, 1963 PL 88-206, as amended
Safe Drinking Water Act, PL 99-339

United States - Canada

Great Lakes Water Quality Agreement, 1978, as amended

Appendix 4.2

Desirable Ambient Air Quality Criteria (OMOE)

Appendix 4.2 Desirable ambient air quality criteria established by the Ontario Ministry of the Environment

Parameter	Desirable Ambient Air Quality Criteria	Prime Reasons for Establishing Criteria or Monitoring Parameter
Carbon monoxide	30 ppm averaged for 1 hour 13 ppm averaged for 8 hours	Protection of human health Protection of human health
Fluoridation rate	40 μg of fluorides/100 cm^2 of lined filter paper in 30 days during April 15 to October 15 80 μg of fluorides/100 cm^2 of lined filter paper in 30 days during October 16 to April 14	Protection of vegetation Protection of vegetation (less restrictive cirterion during the non-growing season)
Hydrocarbons	None	Effects of hydrocarbons vary widely depending on their chemical-physical nature
Hydrogen Sulphide	0.02 ppm averaged for 1 hour	Protection against offensive odours
Mercaptans	0.01 ppm averaged for 1 hour	Protection against offensive odours
Nitric oxide	None	Reacts with oxygen to produce NO_2
Nitrogen dioxide	0.02 ppm averaged for 1 hour 0.10 ppm averaged for 24 hours	Protection of human health and protection against odours Protection of human health and protection against odours
Oxides of nitrogen	None	
Ozone	0.08 ppm averaged for 1 hour	Protection of vegetation, adverse health effects
Sulphur dioxide	0.25 ppm averaged for 1 hour 0.10 ppm averaged for 1 day (24 hours) 0.02 ppm average for 1 year	Protection of vegetation Protection of human health Protection of vegetation
Suspended particulates	120 $\mu g/m^3$ averaged for 24 hours A geometric mean of 60 $\mu g/m^3$ during 1 year	Based on health effects in conjunction with elevated levels of SO_2 and impairment of visibility Based on public awareness of visible pollution
Cadmium in suspended particulates	2.0 $\mu g/m^3$ averaged for 24 hours	Protection of human health
Lead in suspended particulates	5 $\mu g/m^3$ averaged for 24 hours A geometric mean of 2 $\mu g/m^3$ over a 30 day period	Protection of human health Protection of human health
Nickel in suspended particulates	2.0 $\mu g/m^3$ averaged for 24 hours	Protection of vegetation
Vanadium in suspended particulates	2.0 $\mu g/m^3$ averaged for 24 hours	Protection of human health

Appendix 4.3

Ontario Drinking Water Quality Objectives (ODWO)

Appendix 4.3 Ontario Provincial Drinking Water Quality Objectives (ODWO)[1]

Parameter[2]	Maximum Acceptable Concentration	Maximum Desirable Concentration	Interim Maximum Acceptable Concentration
Alkalinity			
Ammonia, mg/L			
Barium, mg/L	1.0		
Boron, mg/L	5.0		
Chloride, mg/L		250	
Chlorine, mg/L			
Color, TCU		5	
Copper, mg/L		1.0	
Cyanide, free (mg/L)	0.2		
Dissolved Gases			
Dissolved Oxygen, mg/L			
Fluoride, mg/L	2.4		
Hydrogen Sulfide, mg/L		Inoffensive	
Manganese, mg/L		0.05	
Methane, $1/m^3$		3	
Nitrate (as N), mg/L[3]	10.0		
Nitrite (as N), mg/L	1.0		
Heavy Metals, μg/L			
Arsenic	50		
Beryllium			
Cadmium	5		
Chromium	50		
Copper			
Iron		300	
Lead	50		
Mercury	1		
Nickel			
Selenium	10		
Silver	50		
Zinc		5.0	
Uranium, mg/L			0.02
Bacteria (per 100ml)			
Standard Plate Count	500		
Total Coliform	5		
Fecal Coliform			
Fecal Streptocci	0		
Pseudomonas aeruginosa	0		

Appendix 4.3. cont'd

Parameter [2]	Maximum Acceptable Concentration	Maximum Desirable Concentration	Interim Maximum Acceptable Concentration
Staphylococcus aureus	0		
Trihalomethanes, mg/L [4]	0.35		
Industrial Organics, mg/L			
Dibutylphthalate			
Diethylhexyphthalate			
Other Phthalates			
Mirex			
Polychorinated Biphenyls			0.003
Polybrominated Biphenyls			
NTA, mg/L	0.05		
Odour		Inoffensive	
Oil & Grease			
Organic Nitrogen,mg/L [5]		0.15	
pH			
Phenols, ug/L		2	
Phosphorus(total),mg/L			
Radionuclides, Bq/L			
Cesium 137	50		
Iodine 131	10		
Radium 226	1		
Strontium 90	10		
Tritium	40,000		
Sulphate, mg/L		500	
Taste		Inoffensive	
Temperature, °C		15	
Total Dissolved Solids, mg/L		500	
Total Organic Carbon, mg/L		5.0	
Turbidity			
Pesticides, µg/L [6]			
Aldrin+/Dieldrin	0.7		
Carbaryl	90		
Chlordane	7		
Chlorpyrifos (Dusban)	90		
Diazinon	20		
Dicamba (Banvel)	120		
Diquat	70		

Appendix 4.3. cont'd

Parameter [2]	Maximum Acceptable Concentration	Maximum Desirable Concentration	Interim Maximum Acceptable Concentration
Diuron	150		
Dalapon			
Endosulphan			
Endrin			
Fenthion (Baytex)			
Guthion			
Heptachlor & Heptachlor Epoxide	3		
Lindane	4		
Malathion	190		
Methoxychlor	900		
Methyl Parathion	7		
Parathion	50		
Pyrethrum			10
Simazine			
Toxaphene			
DDT & Metabolites	30		
2,4-D (BEE)	100		
2,4,5-TP	10		
Dibenzofurans/dioxins (pg/L)			15

(1) From Ontario Drinking Water Objectives, 1983 (ISBN. 0-7729 - 2725-1)
(2) Unless otherwise state the limits for each substance refer to the sum of all forms present.
(3) Where both nitrate and nitrite are present, the total nitrate plus nitrite-nitrogen should not exceed 10 mg/L.
(4) The term "trihalomethanes" comprises chloroform, bromodichlaromethane, chlorodibromomethane and bromoform, and their concentration as determined by the gas sparge or purge equivalent method (i.e. actual concentration) should not exceed 0.35 mg/L at any time.
(5) Total kjeldahl nitrogen minus ammonia nitrogen.
(6) When more than one of these pesticides is present, the "total pesticides" shall not exceed the sum of their Maximum Acceptable Concentrations or Oil mg/L whichever is less.

Appendix 4.4

Summary of Maximum Contaminant Levels/Goals and Monitoring Requirements For Community Water Systems In Michigan

SUMMARY OF MAXIMUM CONTAMINANT LEVELS / GOALS AND MONITORING REQUIREMENTS FOR COMMUNITY WATER SYSTEMS IN MICHIGAN

	Contaminant	MCL	MCLG	Monitoring Requirement	Comments
MICRO BIOLOGY	Coliform Bacteria	Zero - using fermentation tube <1/100 ml - using membrane filter		The number of samples required is based on the population served.	Distribution system sampling locations
NATURAL RADIOACTIVITY	Gross Alpha Radium-226 plus Radium-228	15 pCi/l 5 pCi/l		Compliance based on the analysis of an annual composite of 4 consecutive quarterly samples or the average of the analysis of 4 quarterly samples. Monitoring frequency shall be at least once every 4 years. More frequent monitoring shall be required of vulnerable systems. If annual record establishes that the average annual concentration is less than half theMCL a single sample may be substituted for quarterly sampling procedure.	Distribution system sampling location Samples are screened as follows: 1. Test for Gross Alpha 2. If Gross Alpha exceeds 5 pCi/l test for Ra-226 3. If Radium-226 exceeds 3 pCi/l test for Ra-228
MANMADE RADIOACTIVITY	Gross Beta and Photon Radioactivity	4 millirem/yr total body or any internal organ.		Monitoring is required by surface water supplies serving greater than 100,000 persons and any other supplies designated by the state. Analysis of a composite of 4 consecutive quarterly samples or analysis of 4 quarterly samples is required. Frequency : Every 4 years. Composite of 4 consecutive quarterly samples or analysis of 4 quarterly samples. Every 4 years after initial sampling.	Distribution system sampling location Screening Level: Gross Beta Activity 15 pCi/l Tritium 20,000 pCi/l Strontium 90 8 pCi/l
PHYSICAL	Corrosivity	must be noncorrosive		Ground Water: 1 sample per plant Surface Water: 2 samples/plant (one summer, one winter)	Determination of Corrosivity is based on Langlier Index
	Turbidity	<1 NTU average each month <5 NTU average two day period		Surface Water only - 1 sample per day per treatment plant.	Sampling point at point of entry to distribution system.

SUMMARY OF MAXIMUM CONTAMINANT LEVELS / GOALS AND MONITORING REQUIREMENTS FOR COMMUNITY WATER SYSTEMS IN MICHIGAN

	Contaminant	MCL	MCLG	Monitoring Requirement	Comments
INORGANIC CHEMICALS	Arsenic	0.05 mg/l		As and Ba - Monitoring schedule determined by MDPH based on water supply vulnerability. All other metals - 1 sample every 9 years unless designated as vulnerable by MDPH.	Distribution system sampling location
	Barium	1.0 mg/l			
	Cadmium	0.010 mg/l			
	Chromium	0.05 mg/l			
	Lead	0.05 mg/l			
	Mercury	0.002 mg/l			
	Selenium	0.01 mg/l			
	Silver	0.05 mg/l			
	Fluoride	4.0 mg/l		Ground water systems: 1 sample per plant every 3 years. Surface Water Source or Complete treatment systems: 1/plant/year.	Sampling point at point of entry to distribution system, and preceding treatment for limited treatment plants.
	Nitrate (as N)	10. mg/l			
	Sodium	--			
ORGANIC CHEMICALS	**Pesticides/Herbicides**			Surface Water only: 1 sample every 9 years except for vulnerable supplies.	Distribution system sampling location
	Endrin	0.0002 mg/l			
	Lindane	0.004 mg/l			
	Methoxychlor	0.1 mg/l			
	Toxaphene	0.005 mg/l			
	2,4-D	0.1 mg/l			
	2,4,5-TP (Silvex)	0.01 mg/l			
	Trihalomethanes (THM's)			Monitoring is required for all chlorinated supplies which utilize their own source. 4 samples per quarter to 1 sample per year (maximum formation potential) frequency. Monitoring frequency based on vulnerability of source and/or maximum potential formation results.	Distribution system sampling locations (Maximum Formation Potential samples from entry to distribution system)
	Chloroform	Total THM/s 0.10 mg/l			
	Chlorodibromomethane				
	Bromodichloromethane				
	Bromoform				
	Volatile Organic Chemicals			Population / Monitoring Completed By: >10,000 — 12-31-88; 3,300-10,000 — 12-31-89; <3,300 — 12-31-91	MCL effective 1-19-89. Monitoring to be performed at point of entry into system (an individual well, a plant tap from a treatment plant or the discharge from a pumping station or common header from a group of wells).
	Benzene	0.005 mg/l	zero	4 samples (1 per quarter). If no VOCs detected in first sample for groundwater systems or first year's quarterly samples for surface water systems, and system not vulnerable, sampling may be reduced to one sample and frequency to five years. If no VOCs and system vulnerable, repeat sampling as follows: For groundwater systems >500 service connections resample within 3 years, <500 service connections resample within 5 years. For surface water systems, monitor at a frequency of 1 sample every 3 years. If VOCs are detected, quarterly monitoring is required.	
	Vinyl Chloride	0.002 mg/l	zero		
	Carbon Tetrachloride	0.005 mg/l	zero		
	1,2 Dichloroethane	0.005 mg/l	zero		
	Trichloroethylene	0.005 mg/l	zero		
	para-Dichlorobenzene	0.075 mg/l	0.075 mg/l		
	1,1-Dichloroethylene	0.007 mg/l	0.007 mg/l		
	1,1,1-Trichloroethane	0.20 mg/l	0.200 mg/l		

Appendix 4.4 (Cont'd)

	Contaminant	MCL	MCLG	Monitoring Requirement	Comments
	Unregulated				
	Bromobenzene	--		Category I, monitoring requirement same as for Volatile Organic Chemicals.	
	Bromodichloromethane	--			
	Bromoform	--			
	Bromomethane	--			
	Chlorobenzene	--			
	Chlorodibromomethane	--			
	Chloroethane	--			
	Chloroform	--			
	Chloromethane	--			
	o-Chlorotoluene	--			
	p-Chlorotoluene	--			
	Dibromomethane	--			
	m-Dichlorobenzene	--			
	o-Dichlorobenzene	--			
	trans-1,2-Dichloroethylene	--			
	cis-1,2-Dichloroethylene	--			
	Dichloromethane	--			
	1,1-Dichloroethane	--			
	1,1-Dichloropropene	--			
	1,3-Dichloropropene	--			
	1,2-Dichloropropane	--			
	1,3-Dichloropropane	--			
	2,2-Dichloropropane	--			
	Ethylbenzene	--			
	Styrene	--			
	1,1,2-Trichloroethane	--			
	1,1,1,2-Tetrachloroethane	--			
	1,1,2,2-Tetrachloroethane	--			
	Tetrachloroethylene	--			
	1,2,3-Trichloropropane	--			
	Toluene	--			
	p-xylene	--			
	o-xylene	--			
	m-xylene	--			
	Ethylene Dibromide (EDB)	--		Category II, required monitoring only for vulnerable systems.	
	1,2-Dibromo-3-Chloropropane (DBCP)	--			
	Bromochloromethane	--		Category III, required at MDPH discretion.	
	n-Butylbenzene	--			
	Dichlorodifluoromethane	--			
	Fluorotrichloromethane	--			
	Hexachlorobutadiene	--			
	Isopropyl benzene	--			
	p-Isopropyltoluene	--			
	Naphthalene	--			
	n-Propylbenzene	--			
	Secbutylbenzene	--			
	Tertbutylbenzene	--			
	1,2,3-Trichlorobenzene	--			
	1,2,4-Trichlorobenzene	--			
	1,2,4-Trimethylbenzene	--			
	1,3,5-Trimethylbenzene	--			

Appendix 5.1

International Lake Superior Board of Control Report On Lake Superior Regulation: Monthly Lake Superior Outflow

Appendix 5.1 International Lake Superior Board of Control
Report on Lake Superior Regulation:
Monthly Lake Superior Outflow.

YEAR & MONTH	OUTFLOW IN CFS THROUGH													LAKE SUPERIOR OUTFLOW
	POWER CANALS					NAVIGATION CANALS			DOMESTIC USAGE				FISHERY	
	U.S. GOVT. HYDRO	EDISON SAULT ELECTRIC CO.	U.S. TOTAL	GREAT LAKES POWER LIMITED	TOTAL IN POWER CANALS	UNITED STATES	CANADA	TOTAL IN NAVIGATION CANALS	SAULT STE. MARIE U.S. & CANADA	ALGOMA STEEL	ABITIBI PRICE	TOTAL DOMESTIC USAGE	ST. MARYS RAPIDS	
JAN 90	11200	20466	31666	31836	63502	0	0	0	11	204	12	227	3330	67067
FEB	11032	20619	31651	31876	63527	0	0	0	11	206	12	229	3305	67061
MAR	11139	20691	31830	31793	63623	53	0	53	11	210	12	233	3267	67175
APR	10525	20580	31105	31697	62802	397	0	397	11	211	12	234	3229	66662
MAY	11316	24326	35642	32165	67807	514	0	514	11	216	12	239	3347	71907
JUN	11330	15421	26751	25380	52131	652	0	652	11	204	12	227	3494	56504
JUL*	11320	19255	30575	30707	61282	750	0	750	14	209	12	235	3545	65812
AUG	11005	18391	29396	30792	60188	684	0	684	14	18	12	44	3551	64467
SEP	11238	15074	26312	26355	52667	563	0	563	13	78	12	103	11713	65046
OCT	11250	16162	27412	27481	54893	454	0	454	11	49	12	72	3568	58987
NOV	10979	19981	30960	30799	61759	420	0	420	10	53	12	75	3571	65824
DEC	10998	17136	28134	28410	56544	410	0	410	10	180	12	202	3526	60692
JAN 91	11118	14394	25512	26227	51739	79	0	79	10	205	12	227	3472	55517
FEB	10564	15104	25668	25874	51542	0	0	0	10	194	12	216	3440	55198
MAR														
APR														
MAY														
JUN														
JUL														
AUG														
SEP														
OCT														
NOV														
DEC														

* Revised, April 16, 1991.

Appendix 6.1

PAH Concentrations Associated with the Aqueous Phase, Particulate Phase and Whole Water from the St. Marys River, 1985 and 1986

Table 6APP.1 PAHs associated with the aqueous phase in the St. Marys River, 1985. (from UGLCCS 1988) (See Figure 6.6 for sample locations).

PAH (ng/L)	Station									
	2	3	4	5	7	9	10	12	13	14
Phenanthrene	1.48	1.90	1.04	7.50	15.90	13.56	3.45	NA	1.51	1.82
Anthracene	0.18	0.29	0.06	0.88	1.70	1.86	0.36	NA	0.22	0.15
Fluoranthene	0.93	1.33	0.91	10.00	11.64	8.73	3.24	NA	1.33	0.94
Pyrene	0.26	0.40	0.15	1.30	1.59	1.57	0.54	NA	0.32	0.15
Benzo(a)anthracene	-	-	-	0.38	0.23	-	-	NA	-	-
Chrysene	-	0.2	-	0.34	0.33	-	-	NA	-	-
Benzo(b)fluoranthene	0.54	0.05	0.04	0.34	0.29	-	0.11	NA	0.06	0.05
Perylene	0.49	0.09	0.07	-	-	-	-	NA	-	-
Benzo(k)fluoranthene	-	6	-	0.20	-	-	0.07	NA	0.03	0.03
Benzo(a)pyrene	-	-	-	0.08	-	-	0.02	NA	0.02	-
Benzo(g,h,i)perylene	0.09	-	0.18	-	-	0.12	-	NA	0.05	0.03
Coronene	0.02	0.18 0.02	0.02	0.29	0.12	0.06	0.04	NA	0.02	0.02
Total PAHs	3.99	4.46	2.47	21.31	31.8	25.9	7.83	NA	3.56	3.19

NA = Sample not analyzed
- = Not detected

Table 6APP.2 PAHs associated with centrifuged particulate matter in the St. Marys River, 1986. (from UGLCCS 1988). (See Figure 6.7 for sample locations).

PAHs (ng/g dry weight)	MDL (ng/g)	Stations															
		1	2	4		5	6	8	9		10		11		12	14	15	
			T	T	B	B	B	T	T	B	T	B	T	B	B	B	T	B
Naphthalene	50	ND	TR	ND	ND	ND	2,934	80	1,06	801	ND	ND	1,94	640	278	ND	184	ND
Acenaphthylene	50	ND	TR	ND	ND	ND	623	ND	4	ND	ND	ND	8	ND	ND	ND	ND	ND
Acenaphthene	50	ND	TR	ND	ND	ND	1,086	TR	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9 H Fluorene	60	ND	TR	ND	ND	ND	303	TR	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	40	TR	TR	TR	189	ND	8,379	108	ND	718	ND	ND	ND	447	ND	ND	189	ND
Anthracene	40	TR	TR	ND	ND	ND	2,444	120	509	ND	ND	ND	ND	120	ND	ND	ND	ND
Fluoranthene	40	TR	TR	489	ND	ND	7,067	185	ND	1,37	ND	1,35	ND	957	624	111	335	ND
Pyrene	40	TR	TR	479	290	ND	6,310	151	1,11	7	ND	8	ND	690	469	87	295	ND
Chrysene	50	TR	TR	7,995	233	ND	7,266	78	9	689	ND	1,26	ND	538	362	ND	264	ND
Benzo(a)anthracene	50	TR	TR	1,337	286	ND	7,684	109	919	979	ND	2	ND	680	465	ND	408	ND
Benzo(a)pyrene	50	ND	TR	593	ND	ND	3,882	67	618	1,25	ND	TR	ND	535	283	ND	ND	ND
Benzo(k) and	50	TR	TR	1,144	330	ND	5,819	122	865	8	ND	1,03	ND	933	496	ND	511	ND
Benzo(b)fluoranthene	50	ND	TR	ND	ND	ND	336	ND	465	650	ND	5	ND	ND	ND	ND	ND	ND
Dibenzo(a,h)anthracene	50	ND	TR	TR	84	ND	822	TR	1,00	1,35	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	50	ND	TR	ND	TR	ND	731	TR	2	0	ND	1,41	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-c,d)pyrene									ND	ND		9	ND					
									ND	TR		ND						
									ND	TR		ND						
												ND						
Total PAHs		TR	TR 12	,046 1,	412	ND 55	686 1,	020 6,	561 7,	822	ND 5,	074 1,	948 5,	540 2,	977	198 2,	186	ND

ND - Not detected
TR - Trace

T - Sample taken 1.5 m below surface
B - Sample taken 0.5 m off bottom

Table 6APP.3 Estimated concentrations of PAHs associated with the aqueous phase in the St. Marys River, 1986 (from UGLCCS 1988). (See Figure 6.7 for sample locations).

PAHs (ng/L)	Stations																
	1	2	4		5	6	8	9		10		11		12	14	15	
		T	T	B	B	B	T	T	B	T	B	T	B	B	B	T	B
Naphthalene	NA	NA	NA	NA	NA	1,310.	35.7	475.2	357.7	NA	NA	870.1	285.8	124.	NA	82.1	NA
Acenaphthylene	NA	NA	NA	NA	NA	57	3	7	9	NA	NA	4	8	18NA	NA	9	NA
Acenaphthene	NA	NA	NA	NA	NA	74.90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9 H Fluorene	NA	NA	NA	NA	NA	50.80	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	NA	NA	NA	6.55	NA	22.98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Anthracene	NA	NA	NA	NA	NA	290.53	3.74	17.61	24.90	NA	NA	NA	15.50	NA	NA	NA	NA
Fluoranthene	NA	NA	2.50	NA	NA	86.72	4.26	NA	NA	NA	6.81	NA	4.26	3.13	0.5	NA	NA
Pyrene	NA	NA	3.02	1.83	NA	35.42	0.93	5.61	6.90	NA	7.96	NA	4.80	2.96	6	1.68	NA
Chrysene	NA	NA	17.90	0.52	NA	39.81	0.95	5.80	4.35	NA	NA	NA	4.35	0.8	0.5	1.86	NA
Benzo(a)anthracene	NA	NA	2.38	0.51	NA	16.27	0.17	1.38	2.19	NA	1.84	NA	1.20	0.83	5	0.59	NA
Benzo(a)pyrene	NA	NA	0.54	NA	NA	13.66	0.19	1.54	2.24	NA	NA	NA	1.21	0.26	NA	0.73	NA
Benzo(k) and	NA	NA	0.23	0.07	NA	3.54	0.06	0.42	0.59	NA	0.28	NA	0.49	0.10	NA	NA	NA
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	1.16	0.02	0.20	0.27	NA	NA	NA	0.19	NA	NA	0.10	NA
Dibenzo(a,h)anthracene	NA	NA	NA	0.01	NA	0.11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	NA	NA	NA	NA	NA	0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indeno(1,2,3-c,d)pyrene						0.02	NA	NA	NA			NA	NA		NA	NA	
															NA		
Total PAHs	NA	NA	26.57	9.49	NA	1,946. 54	46.0 5	507.8 3	399.2 3	NA	16.8 9	870.1 4	317.8 8	132. 27	1.1 1	87.1 5	NA

ND - Not detected
TR - Trace
NA - Not applicable as PAHs were not detected on the centrifuged particulate matter (Table 6APP.2)

T - Sample taken 1.5 m below surface
B - Sample taken 0.5 m off bottom

Table 6APP.4 Estimated concentrations of PAHs in whole water (aqueous plus particulate phases) of the St. Marys River, 1986 (from UGLCCS 1988). (See Figure 6.7 for sample locations).

PAHs (ng/L)	Stations																
	1	2	4		5	6	8	9		10		11		12	14	15	
		T	T	B	B	B	T	T	B	T	B	T	B	B	B	T	B
Naphthalene	NA	NA	NA	NA	NA	1,414.	36.3	483.1	363.7	NA	NA	875.2	287.8	124.	NA	82.8	NA
Acenaphthylene	NA	NA	NA	NA	NA	43	3	4	2	NA	NA	0	6	18NA	NA	5	NA
Acenaphthene	NA	NA	NA	NA	NA	96.96	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9 H Fluorene	NA	NA	NA	NA	NA	78.24	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	NA	NA	NA	6.76	NA	33.71	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Anthracene	NA	NA	NA	NA	NA	587.15	4.54	21.37	30.21	NA	NA	NA	16.88	NA	NA	NA	NA
Fluoranthene	NA	NA	3.04	NA	NA	173.23	5.15	NA	NA	NA	16.7	NA	4.63	3.19	0.7	NA	NA
Pyrene	NA	NA	3.55	2.15	NA	285.59	2.30	13.89	17.09	NA	2	NA	7.76	3.01	7	2.88	NA
Chrysene	NA	NA	26.69	0.78	NA	263.19	2.07	12.60	9.45	NA	17.1	NA	6.49	0.85	0.7	2.92	NA
Benzo(a)anthracene	NA	NA	3.85	0.82	NA	273.48	0.75	6.96	9.44	NA	8	NA	2.87	0.87	1	1.54	NA
Benzo(a)pyrene	NA	NA	1.19	NA	NA	285.68	1.00	7.94	11.55	NA	NA	NA	3.32	0.29	NA	1.54	NA
Benzo(k) and	NA	NA	1.49	0.43	NA	140.96	0.56	3.87	5.40	NA	9.40	NA	2.15	0.15	NA	NA	NA
Benzo(b)fluoranthene	NA	NA	NA	NA	NA	207.15	0.93	7.61	10.26	NA	NA	NA	3.08	NA	NA	1.94	NA
Dibenzo(a,h)anthracene	NA	NA	NA	0.10	NA	12.00	NA	NA	NA	NA	10.6	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	NA	NA	NA	NA	NA	29.15	NA	NA	NA	NA	4	NA	NA	NA	NA	NA	NA
Indeno(1,2,3-c,d)pyrene						0.02	NA	NA	NA		NA	NA	NA		NA	NA	
											NA				NA		
											NA						
Total PAHs	NA	NA	39.81	11.0 4	NA	3,891. 94	53.6 3	556.3 8	457.1 2	NA	53.8 4	875.2 0	335.0 4	132. 57	1.4 8	94.3 2	NA

ND - Not detected
TR - Trace
NA - Not applicable as PAHs were not detected on the centrifuged particulate matter (Table 6APP.2)

T - Sample taken 1.5 m below surface
B - Sample taken 0.5 m off bottom

Appendix 6.2

Results From the U.S. EPA/FWS and OMOE 1985 Surficial Sediment Sampling Surveys from the St. Marys River (from Hesselberg and Hamdy 1987)

Table 8 Physical parameters in the St. Mary's River 1985
National Fisheries Center - Great Lakes
Ann Arbor MI 313(994)3331

STN NO.	SIDE	LATITUDE			LONGITUDE			8%	4%	10%	16%	20%	50%	100%	200%	%PASSED BY 200	TOTAL %	TOTAL SOLIDS
25	C	46	27	30	84	29	12	0.0	0.0	0.3	0.3	1.2	13.3	82.4	2.4	0.1	100.0	75.5
31	A	46	26	20	84	28	53	0.0	0.0	0.3	0.2	0.8	17.4	39.9	22.7	18.6	99.9	62.9
32	A	46	26	35	84	27	58	0.0	0.1	2.2	5.0	3.1	8.9	16.7	25.3	38.7	100.0	56.4
26	C	46	28	13	84	28	10	0.0	0.0	0.8	5.4	5.6	4.6	7.0	20.3	56.4	100.1	34.7
16	C	46	29	3	84	27	15	0.0	0.0	0.2	0.1	0.1	0.2	38.5	46.3	14.7	100.1	62.9
17	A	46	29	22	84	25	9	0.0	0.0	0.0	3.6	3.7	11.5	9.6	25.2	48.3	99.9	60.4
7	C	46	30	28	84	25	27	0.0	0.0	0.5	0.5	0.4	3.5	44.3	23.9	26.9	100.0	58.7
18	A	46	29	32	84	24	10	0.0	0.0	0.0	0.8	3.9	6.3	9.9	33.3	45.7	99.9	52.9
8	C	46	30	20	84	23	25	0.0	0.0	1.4	1.0	7.4	8.0	15.7	22.0	44.5	100.0	34.4
9	C	46	30	52	84	22	41	0.0	0.0	1.0	2.0	0.5	0.7	5.8	26.0	63.1	99.9	60.5
10	C	46	30	36	84	20	36	0.0	0.0	0.7	1.3	1.5	3.6	33.9	35.1	26.0	100.1	56.3
11	C	46	30	8	84	18	50	0.0	0.0	1.3	2.3	1.9	4.9	10.2	30.1	49.3	100.0	32.1
19	A	46	29	31	84	18	50	0.0	0.0	0.4	0.1	0.2	1.5	17.8	41.3	38.8	100.1	65.9
20	C	46	29	40	84	17	37	0.0	0.0	0.4	0.6	1.2	5.0	16.3	26.0	49.6	99.9	46.9
21	A	46	29	33	84	16	40	0.0	0.0	0.5	0.4	0.6	5.3	7.7	27.4	58.0	99.9	34.1
12	C	46	30	11	84	15	19	0.0	0.0	0.3	0.2	0.6	2.5	9.4	44.3	42.7	100.0	30.5
13	A	46	30	51	84	14	34	0.0	1.6	2.3	5.8	15.2	7.8	8.9	18.8	39.5	99.9	21.7
2	C	46	32	11	84	13	22	*	*	*	*	*	*	*	*	*	*	15.8
3	C	46	32	24	84	12	15	0.0	0.0	0.1	0.1	0.3	3.2	46.4	17.7	32.1	99.9	62.7
1	C	46	32	45	84	11	29	0.0	0.0	0.6	0.3	1.5	5.5	6.4	14.9	71.0	100.1	49.2
4	A	46	31	57	84	11	34	0.0	0.0	1.8	5.1	20.2	9.5	9.7	21.7	32.0	100.0	22.2
5	C	46	31	37	84	9	41	0.1	0.0	0.1	0.2	0.5	20.5	54.9	16.4	7.3	100.0	29.6
6	C	46	31	45	84	7	22	0.0	0.0	0.2	0.4	1.0	14.6	42.7	27.6	13.6	100.1	54.9
14	C	46	30	33	84	6	45	0.0	0.0	0.4	0.2	0.2	28.9	46.9	7.6	15.8	100.0	63.3
15	C	46	30	26	84	6	24	0.0	0.0	0.0	0.0	0.2	4.5	42.5	31.3	21.5	100.0	59.4
23	A	46	29	30	84	7	35	0.0	0.0	0.5	9.4	3.0	5.0	13.3	19.1	49.6	99.9	27.1
24	C	46	29	15	84	5	19	0.8	0.0	0.5	0.1	0.0	15.3	54.1	16.8	11.5	99.9	69.2
22	A	46	29	51	84	8	40	0.0	0.0	0.3	0.7	5.7	8.7	12.6	17.0	55.0	100.0	42.1
30	C	46	28	27	84	5	58	0.0	0.0	0.0	0.7	8.0	3.7	5.4	26.5	56.4	100.7	43.9
29	C	46	28	5	84	7	31	0.0	0.0	1.1	10.4	11.6	16.8	16.0	13.4	30.4	99.7	27.4
28	A	46	27	35	84	9	26	0.0	0.1	0.0	0.1	0.3	2.9	40.8	25.8	30.1	100.1	63.6
33	C	46	26	45	84	6	8	0.0	0.0	0.0	0.0	0.1	3.2	76.7	16.7	3.2	99.9	67.4
36	A	46	26	59	84	8	55	0.0	0.0	2.1	0.5	1.0	12.3	11.0	24.5	48.5	99.9	43.0
35	A	46	26	53	84	10	38	0.0	0.0	21.8	8.1	4.1	10.6	17.8	30.2	7.2	99.8	48.6
37	C	46	26	24	84	8	0	0.0	1.6	0.7	0.8	0.5	2.0	63.6	28.3	2.6	100.1	68.2
43	C	46	25	20	84	6	58	0.0	0.0	0.1	0.3	0.6	2.0	48.0	32.3	16.6	99.9	68.7
44	C	46	25	30	84	6	22	0.0	0.0	0.0	0.1	0.2	0.2	43.0	44.9	11.5	99.9	67.4
42	A	46	25	34	84	9	7	0.0	0.0	0.0	0.1	1.5	1.4	6.6	58.0	32.4	100.0	66.1
41	A	46	25	36	84	10	6	0.0	0.0	0.2	2.3	4.2	2.2	2.2	31.9	56.9	99.9	68.5
48	C	46	24	27	84	7	36	0.0	0.0	0.3	1.8	2.4	15.5	58.4	19.7	1.9	100.0	66.7
47	A	46	24	27	84	9	7	0.0	0.0	0.2	0.1	0.1	0.2	29.9	60.2	9.4	100.1	61.0
46	A	46	24	23	84	10	23	0.0	0.0	0.0	0.1	0.1	2.9	15.5	54.8	26.2	99.6	63.8
52	C	46	23	13	84	7	50	0.0	0.4	1.0	5.6	8.2	4.8	16.4	50.8	12.4	99.6	63.3
51	A	46	22	54	84	9	2	0.0	0.0	0.2	1.4	10.4	12.2	10.0	18.4	47.6	100.2	39.4
56	[illegible]	46	21	10	84	7	20	0.0	0.0	11.2	20	20.4	13.2	8.8	7.2	16.4	97.6	36.0

Table 4 cont. Physical parameters in the St. Mary's River - 1985
National Fisheries Center - Great Lakes
Ann Arbor Mi 31300043031

STN NO.	SITE	LATITUDE			LONGITUDE			3%	4%	10%	16%	20%	50%	100%	200%	%PASSED BY 200	TOTAL %	TOTAL SOLIDS
59	A	46	20	8	84	7	10	0.0	1.0	6.8	5.2	5.2	10.2	52.2	13.0	5.4	99.0	65.3
60	C	46	20	13	84	5	41	0.0	2.0	20.2	19.6	22.0	11.6	7.2	5.2	6.8	97.6	34.9
65	C	46	19	11	84	5	38	0.0	1.2	22.2	5.6	11.6	5.8	5.8	10.6	36.8	99.6	52.4
66	C	46	18	57	84	4	40	0.0	2.0	16.2	3.4	10.2	4.2	1.2	8.0	53.4	90.6	55.1
69	C	46	17	52	84	3	27	0.0	0.4	5.6	5.6	22.0	10.2	12.0	15.6	18.0	92.4	39.9
70	C	46	18	26	84	2	30	0.0	0.0	13.4	16.6	17.2	0.2	4.0	5.8	27.0	99.0	42.1
71	C	46	18	6	84	0	59	0.0	0.6	17.6	13.8	26.6	14.2	6.8	6.0	12.4	98.0	28.1
27	A	46	28	36	84	18	10	0.0	0.0	0.1	0.1	0.2	1.8	16.7	31.0	49.2	99.9	67.4
31	A	46	27	19	84	14	50	0.0	0.0	17.7	21.2	6.9	5.9	8.9	18.4	21.0	100.0	26.6
33	A	46	26	57	84	15	13	0.0	0.0	0.1	4.8	2.2	29.6	16.0	29.2	18.2	100.1	39.3
37	A	46	25	59	84	15	35	0.0	0.0	0.0	0.1	0.5	0.7	1.8	55.3	41.7	100.1	67.1
40	A	46	25	40	84	14	25	0.0	0.0	0.2	3.6	5.0	3.1	6.0	19.2	61.6	99.5	64.7
45	A	46	24	20	84	14	50	0.0	0.0	0.0	2.3	2.4	4.2	4.7	21.2	65.2	100.0	65.9
49	A	46	22	54	84	13	35	0.0	0.0	0.2	0.8	5.6	5.6	4.0	30.2	52.8	99.2	65.7
50	A	46	22	37	84	12	39	0.0	0.0	0.4	2.3	8.0	25.4	42.9	10.2	10.5	99.7	69.2
53	A	46	22	10	84	13	50	0.0	0.0	2.0	3.6	15.0	24.0	24.6	0.0	16.8	99.0	66.5
54	A	46	21	53	84	12	2	0.0	0.0	0.0	0.6	2.6	0.0	11.6	34.2	47.2	99.2	63.1
55	A	46	21	32	84	11	12	0.0	0.0	0.0	3.2	10.0	11.6	12.0	20.2	41.8	90.8	64.7
57	A	46	20	35	84	12	20	0.0	0.4	1.4	5.8	6.4	4.2	8.0	45.8	27.8	99.8	66.7
58	A	46	20	24	84	11	3	0.0	0.0	3.6	9.6	8.8	5.0	5.6	28.0	39.0	99.6	63.4
61	A	46	19	52	84	12	22	0.0	0.0	10.2	7.0	10.0	5.8	7.4	18.0	39.4	98.6	60.9
62	A	46	19	39	84	10	33	0.0	0.7	0.3	0.1	1.6	30.1	62.0	3.2	0.3	99.1	72.0
67	A	46	17	58	84	13	10	0.0	1.2	37.0	17.4	16.0	8.0	6.8	3.4	13.0	102.8	52.9
72	A	46	17	11	84	13	2	0.0	0.0	0.5	0.2	3.4	10.5	53.4	14.7	16.5	99.2	71.2
74	A	46	15	54	84	11	11	0.0	1.0	8.0	5.0	16.6	11.2	6.4	12.0	39.0	100.0	52.5
77	A	46	14	14	84	10	19	0.0	2.0	4.4	1.7	9.2	9.0	20.1	16.8	36.8	100.0	65.4
82	A	46	13	24	84	9	47	0.0	0.0	0.2	0.0	0.6	14.4	18.4	26.2	40.2	100.0	61.0
01	A	46	13	13	84	10	20	0.0	0.0	0.0	0.0	0.2	0.2	3.2	32.4	60.4	96.4	62.8
76	A	46	14	9	84	11	7	0.0	0.8	18.4	10.6	20.0	19.4	13.8	11.0	6.2	101.0	59.1
80	A	46	13	38	84	12	3	0.0	0.0	0.4	1.2	2.0	2.6	7.8	21.0	64.8	99.8	45.9
86	A	46	12	6	84	12	21	0.0	0.0	0.0	0.2	5.9	31.8	35.9	22.4	4.0	100.2	66.6
87	A	46	11	58	84	10	41	0.0	0.0	0.0	0.0	0.4	4.8	23.4	59.8	11.4	99.8	61.8
85	A	46	12	2	84	13	30	0.0	0.0	0.2	0.4	0.8	12.4	20.8	38.0	27.6	100.2	52.1
91	A	46	10	27	84	13	41	0.0	0.4	0.0	0.0	0.4	8.0	23.2	45.8	21.8	99.6	45.3
92	A	46	10	40	84	12	14	0.0	0.8	0.1	0.0	1.1	15.5	45.6	26.4	10.6	99.8	67.3
93	A	46	11	12	84	10	59	0.0	0.0	0.6	2.0	13.6	19.6	25.2	27.2	11.2	100.2	47.9
88	A	46	11	39	84	9	10	0.0	4.4	0.9	0.0	2.1	16.1	22.8	13.6	39.8	99.7	57.1
94	A	46	11	2	84	9	2	0.0	0.0	0.0	0.4	21.8	27.0	20.0	22.0	8.8	100.0	60.4
63	A	46	19	30	84	8	51	0.0	0.0	9.2	2.4	21.4	20.4	11.6	12.6	21.4	99.0	47.4
64	A	46	19	17	84	8	7	0.0	0.8	17.0	2.4	15.6	6.6	4.2	13.4	33.0	98.0	47.5
68	A	46	17	35	84	7	20	0.0	0.0	8.6	2.2	12.6	10.8	8.2	17.0	40.4	99.8	65.8
73	A	46	16	30	84	7	10	0.0	1.0	8.3	3.0	12.0	10.4	7.7	8.3	49.3	100.0	67.2
75	C	46	15	20	84	5	48	0.0	0.0	2.9	1.0	6.5	4.3	33.5	22.9	35.6	99.7	64.5
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										

Table A cont. Physical parameters in the St. Mary's River - 1985
National Fisheries Center - Great Lakes
Ann Arbor MI 3159943931

STA NO.	STN	LATITUDE			LONGITUDE			3%	4%	10%	16%	35%	50%	100%	200%	PASSED BY 200	TOTAL %	TOTAL SOLIDS
79	C	46	14	16	84	6	20	0.0	0.0	0.0	0.0	0.6	0.8	1.4	20.0	69.0	91.8	54.2
89	H	46	13	10	84	7	8	0.0	0.0	0.2	0.6	1.6	2.4	7.0	19.0	68.6	99.4	46.4
84	C	46	13	3	84	5	20	0.0	0.2	0.0	0.0	1.6	17.0	47.4	23.2	10.2	99.6	59.0
90	H	46	12	53	84	6	17	0.0	0.0	0.0	0.3	8.3	31.6	24.2	28.5	10.2	100.1	54.4
94	H	46	11	25	84	7	17	0.0	0.0	0.0	0.6	2.0	1.8	8.0	19.2	67.2	98.8	47.5
96	H	46	11	13	84	6	8	0.0	0.0	0.0	0.0	0.6	4.0	8.0	13.2	72.4	99.0	44.3
95	H	46	10	55	84	6	47	0.0	0.0	0.2	0.2	0.6	10.1	22.7	41.2	26.4	101.4	71.4
97	H	46	10	4	84	4	52	0.0	0.0	1.2	0.4	0.6	5.0	13.0	21.2	58.4	99.8	47.9
98	H	46	10	15	84	2	59	0.0	0.0	0.0	0.2	0.4	4.0	12.6	22.8	60.2	100.2	52.1
99	H	46	9	33	84	5	14	1.4	0.3	0.2	0.0	4.2	30.5	29.3	29.9	10.0	99.8	68.7
100	H	46	9	25	84	3	49	0.0	0.0	0.0	0.2	0.6	1.4	7.6	29.0	61.0	95.8	45.0
101	H	46	8	57	84	2	56	0.0	0.0	0.2	0.0	0.5	3.0	12.5	22.8	60.5	100.3	37.8
102	H	46	8	56	84	1	14	0.0	0.0	1.0	1.0	1.5	3.5	12.5	35.8	44.5	95.8	35.5
103	H	46	8	16	84	0	41	0.0	0.0	0.0	0.0	0.5	3.5	10.5	24.0	61.0	99.5	39.0
104	C	46	8	10	83	59	39	0.0	0.0	0.0	0.0	0.5	7.4	31.5	46.1	14.3	99.8	71.5
105	H	46	6	41	84	2	16	0.0	0.0	0.3	0.1	2.8	30.7	25.8	18.9	22.0	100.0	73.2
106	H	46	7	2	84	1	17	0.0	0.0	0.6	0.8	1.4	6.2	10.6	21.4	58.8	99.8	50.0
107	C	46	6	46	83	59	18	0.0	0.0	0.4	0.0	0.4	3.4	13.2	26.2	56.2	99.8	44.0
108	H	46	5	40	84	3	47	0.0	0.0	0.2	0.5	6.7	13.2	10.2	36.5	32.9	100.2	63.0
109	H	46	6	2	84	2	50	0.0	0.0	0.0	0.0	1.1	6.0	14.9	31.4	45.7	99.1	34.6
110	H	46	5	40	84	0	19	0.0	1.0	0.0	0.0	0.4	5.8	14.8	25.4	52.6	100.0	49.3
111	H	46	5	40	83	58	55	0.0	0.0	0.8	0.2	1.0	11.0	13.0	37.5	35.5	99.0	34.6
112	C	46	5	19	83	57	50	0.0	0.0	2.4	0.4	4.8	9.0	21.6	40.2	20.6	99.0	48.3
113	H	46	4	0	84	2	3	0.0	0.0	0.0	0.0	0.1	5.6	50.4	34.0	9.7	99.8	67.2
114	H	46	4	10	84	0	27	0.0	0.0	0.0	0.0	0.3	5.3	17.3	35.7	40.4	99.0	32.6
115	H	46	4	6	83	58	55	0.0	0.0	0.0	0.3	0.3	4.0	20.3	29.7	44.3	98.9	33.6
116	H	46	4	30	83	58	15	0.0	0.0	0.7	0.3	1.0	5.0	14.3	25.7	62.0	109.0	30.1
117	H	46	3	7	84	0	38	0.0	0.0	0.0	0.0	0.5	9.8	25.0	25.8	41.2	102.3	31.6
118	H	46	2	43	83	59	40	0.0	0.0	0.6	0.0	0.6	4.4	26.0	25.6	49.0	106.2	39.2
119	H	46	3	2	83	58	2	0.0	0.0	0.0	0.5	1.0	5.0	15.5	36.0	43.0	101.0	27.3
120	H	46	3	5	83	56	21	0.0	0.0	0.0	0.3	1.4	7.4	19.1	29.7	42.3	100.2	27.7
121	H	46	2	10	83	59	10	0.0	0.0	0.0	0.0	0.6	19.8	34.2	19.6	26.0	100.2	47.4
122	H	46	2	0	83	57	55	0.0	0.0	0.2	0.8	2.0	10.0	22.8	30.0	35.5	101.3	29.5
123	H	46	1	43	83	55	57	0.0	0.0	0.3	0.0	0.6	4.0	14.0	29.4	51.7	100.0	32.0
124	H	46	1	41	83	54	48	0.0	0.0	0.0	0.3	1.0	5.7	17.3	37.0	39.0	100.3	29.7
125	H	46	0	50	83	53	44	0.0	0.0	0.0	0.0	0.3	8.8	43.0	38.3	9.5	99.9	69.2

Table 3 Sediment Contaminants in the St. Mary's River - 1985
National Fisheries Center - Great Lakes
Ann Arbor MI [illegible]

Results in mg/kg

STA NO.	SIDE	VOLATILE SOLIDS	OIL		PHENOL		CYANIDE		PCB 1248	PCB 1254	PCB 1260	TOTAL PCB	Hg		Cd	Co	Cr	Cu	Ni	Pb	Zn
25	C	0.25	791		0.5		0.0	t	0.000	0.000	0.000	0.000	0.00	t	0.2	1.2	3	2	2	7	6
31	A	1.57	180	t	0.5		0.0	t	0.000	0.000	0.000	0.000	0.06		0.5	1.7	5	5	4	7	14
32	A	2.31	536	t	0.2		0.0	t	0.000	0.000	0.000	0.000	0.00	t	0.7	3.9	13	12	8	7	26
26	C	6.51	0	t	0.4		0.3	t	0.000	0.000	0.000	0.000	0.00	t	0.9	3.8	14	34	18	30	57
16	C	1.00	0	t	0.8		0.2	t	0.000	0.000	0.000	0.000	0.03		0.3	2.2	6	6	4	11	16
17	A	2.56	563	t	0.0	t	0.2	t	0.066	0.033	0.000	0.099	0.03		0.8	4.6	26	10	9	18	37
7	C	1.84	801		0.2	t	0.1	t	0.000	0.026	0.000	0.026	0.02	t	0.2	2.8	9	7	5	8	30
18	A	2.73	0	t	0.1	t	0.2	t	0.000	0.025	0.000	0.025	0.05		0.4	4.3	18	20	9	18	36
8	C	8.77	999	t	0.2	t	0.2	t	0.000	0.053	0.000	0.053	0.05		1.1	6.6	47	35	16	66	330
9	C	9.29	1330		0.3		0.4	t	0.000	0.000	0.000	0.000	0.00	t	0.3	5.7	26	26	13	52	260
10	C	3.48	0	t	0.1	t	0.2	t	0.000	0.020	0.000	0.020	0.02	t	0.4	2.7	10	13	6	29	60
11	C	15.07	5420		0.3		0.1	t	0.000	0.026	0.000	0.026	0.05		0.6	6.3	78	49	22	62	190
19	A	1.40	0	t	0.0	t	0.0	t	0.000	0.020	0.000	0.020	0.02		1.0	2.3	41	17	8	29	26
20	C	7.70	1520		0.1		1.6		0.000	0.041	0.000	0.041	0.11		0.4	7.0	45	31	17	72	220
21	A	7.86	400	t	0.5		0.0	t	0.000	0.000	0.000	0.000	0.00	t	0.6	5.6	40	44	17	53	150
12	C	8.24	3440		0.1	t	0.6	t	0.000	0.032	0.000	0.032	0.10		0.9	6.3	59	44	24	75	220
13	A	13.94	6500		0.8		0.3	t	0.000	0.068	0.000	0.068	0.16		0.9	7.7	53	49	23	74	210
2	C	17.62	9320		8.2		3.3	t	0.174	0.188	0.000	0.362	0.19		1.8	8.4	58	110	30	130	470
3	C	1.57	360	t	0.1	t	0.0	t	0.000	0.076	0.000	0.076	0.03		0.2	3.1	10	8	6	9	29
1	C	3.00	300	t	0.0	t	0.0	t	0.000	0.000	0.000	0.000	0.04		0.4	4.8	17	16	9	19	64
4	A	13.42	8960		11.0		2.7		0.000	0.092	0.000	0.092	0.13		1.5	8.0	58	70	27	84	260
5	C	5.17	975	t	0.1	t	0.1	t	0.000	0.025	0.000	0.025	0.01	t	0.2	2.8	7	7	4	7	36
6	C	4.16	308	t	0.0	t	0.1	t	0.000	0.000	0.000	0.000	0.03		0.2	7.0	18	19	13	8	46
14	C	1.25	150	t	0.1	t	0.0	t	0.000	0.020	0.000	0.020	0.02	t	0.2	3.6	9	8	7	10	29
15	C	1.85	17	t	0.1	t	0.1	t	0.000	0.020	0.000	0.020	0.10		0.2	5.8	15	12	11	16	62
23	A	7.58	0	t	0.3	t	0.4	t	0.000	0.056	0.000	0.056	0.07		0.3	13.0	56	53	31	76	240
24	C	0.98	3720		0.1	t	0.2	t	0.000	0.025	0.000	0.025	0.04		0.2	2.4	8	6	5	7	28
22	A	3.88	937	t	0.3		0.7	t	0.000	0.051	0.000	0.051	0.11		0.2	10.0	40	32	21	51	150
30	C	4.47	1370		0.1	t	0.8	t	0.000	0.000	0.000	0.000	0.09		0.3	6.2	26	26	14	47	140
29	C	7.40	2010		0.4		2.8		0.000	0.000	0.000	0.000	0.03	t	0.6	11.0	47	53	27	8	240
28	A	1.15	809		2.4		0.1	t	0.000	0.000	0.000	0.000	0.03		0.2	1.9	7	5	4	7	24
38	C	0.66	0	t	0.0	t	0.1	t	0.000	0.000	0.000	0.000	0.01	t	0.2	1.6	4	4	3	7	21
36	A	4.03	805		0.1	t	0.5		0.065	0.000	0.000	0.065	0.00	t	0.4	8.1	33	30	19	42	130
35	A	2.26	0	t	0.1	t	0.1	t	0.041	0.000	0.000	0.041	0.01	t	0.2	9.5	37	23	23	9	45
37	C	0.67	66	t	0.0	t	0.2	t	0.000	0.000	0.000	0.000	0.05		0.2	3.1	10	6	6	7	18
43	C	1.01	364	t	0.1		0.1	t	0.000	0.000	0.000	0.000	0.00	t	0.2	3.7	11	10	7	15	55
44	C	1.39	641		0.1		0.2	t	0.000	0.000	0.000	0.000	0.00	t	0.2	2.6	7	4	5	7	16
42	A	0.67	222	t	0.0	t	0.3	t	0.000	0.000	0.000	0.000	0.01	t	0.2	3.0	8	7	6	7	20
41	A	1.27	172	t	0.0	t	0.4	t	0.000	0.000	0.000	0.000	0.01	t	0.2	4.0	12	10	7	13	55
40	C	1.25	328	t	0.1	t	0.1	t	0.000	0.000	0.000	0.000	0.02		0.2	5.0	17	11	12	10	37
47	A	0.67	441	t	0.1	t	0.1	t	0.000	0.000	0.000	0.000	0.01		0.3	0.9	3	4	2	7	14
46	A	1.04	724		0.2		0.2	t	0.000	0.000	0.000	0.000	0.01		0.2	1.5	5	4	4	7	19
52	C	1.30	0	t	0.3		0.2	t	0.056	0.000	0.000	0.056	0.02		0.2	2.7	8	8	6	12	46
51	A	3.00	581	t	0.2	t	0.2	t	0.000	0.049	0.000	0.049	0.14	t	0.2	6.5	22	21	16	17	75

[illegible] Sediment contaminants in the St. Mary's River - 1985
cont. National Fisheries Center - Great Lakes
Ann Arbor MI 3139943331

Results in mg/kg

STA NO.	SIDE	VOLATILE SOLIDS	OIL	PHENOL	CYANIDE	PCB 1248	PCB 1254	PCB 1260	TOTAL PCB	Hg	Cd	Co	Cr	Cu	Ni	Pb	Zn
59	A	1.07	5090	0.1 t	0.3 t	0.020	0.000	0.000	0.020	0.09	0.2	2.2	7	6	5	10	33
60	C	25.65	320 t	0.2 t	0.2 t	0.046	0.000	0.000	0.046	0.11	0.7	9.5	36	94	22	43	200
65	C	2.10	10800	0.1 t	0.3 t	0.000	0.049	0.000	0.049	0.05	0.3	5.2	31	18	12	15	61
66	C	2.96	347 t	0.0 t	0.2 t	0.000	0.035	0.000	0.035	0.04	0.2	4.5	18	12	10	12	50
68	C	3.37	501 t	0.0 t	0.3 t	0.000	0.034	0.000	0.034	0.01 t	0.2	6.9	25	19	16	19	72
70	C	4.25	510 t	0.1 t	0.3 t	0.000	0.070	0.000	0.070	0.06	0.2	7.5	28	24	16	28	110
71	C	6.04	1200	1.2	0.5 t	0.000	0.086	0.000	0.086	0.07	0.2	11.0	46	35	25	35	150
27	A	1.44	270 t	0.1 t	0.1 t	0.000	0.023	0.000	0.023	0.00 t	0.9	8.5	20	6	7	21	22
34	A	9.21	949 t	0.2 t	2.9	0.070	0.000	0.000	0.070	0.10	0.5	9.2	43	41	25	43	140
33	A	3.48	579 t	0.2	0.4 t	0.000	0.000	0.000	0.000	0.01 t	0.3	3.4	20	15	9	15	49
39	A	0.85	0 t	0.0 t	0.2 t	0.074	0.000	0.000	0.074	0.25	0.2	1.7	6	4	3	7	11
40	A	1.65	44 t	0.0 t	0.1 t	0.090	0.000	0.000	0.090	0.27	0.2	3.0	21	11	7	12	33
45	A	1.78	320 t	0.1 t	0.1 t	0.000	0.000	0.000	0.000	0.02	0.2	6.3	29	14	13	13	27
49	A	1.98	284 t	0.1 t	0.1 t	0.000	0.039	0.000	0.039	0.05	1.2	11.0	45	15	13	95	35
50	A	1.18	256 t	0.0 t	0.1 t	0.000	0.000	0.000	0.000	0.01 t	0.2	3.1	10	7	7	7	21
53	A	1.09	156 t	0.3	0.1 t	0.000	0.040	0.000	0.040	0.00 t	0.2	2.8	13	8	6	8	22
54	A	1.06	311 t	0.6	0.1 t	0.000	0.000	0.000	0.000	0.01 t	0.2	1.4	10	4	3	7	13
55	A	1.36	205 t	0.1	0.2 t	0.000	0.000	0.000	0.000	0.02 t	0.2	2.6	11	8	6	11	20
57	A	1.13	790	0.1 t	0.1 t	0.000	0.000	0.000	0.000	0.02 t	0.2	2.1	11	6	5	7	19
58	A	1.33	54 t	0.1	0.1 t	0.000	0.000	0.000	0.000	0.03	0.2	2.2	12	8	5	10	26
61	A	1.39	0 t	0.2	0.1 t	0.101	0.000	0.000	0.101	0.02	0.2	2.4	20	8	6	8	23
62	A	0.66	235 t	1.0	0.0 t	0.055	0.000	0.000	0.055	0.01 t	0.2	1.0	5	3	2	7	11
67	A	2.91	574 t	0.1 t	0.2 t	0.000	0.033	0.000	0.033	0.01 t	0.2	8.1	33	16	17	9	41
72	A	1.01	16500	0.6	0.1 t	0.000	0.031	0.000	0.031	0.01 t	0.2	2.2	10	5	4	7	16
74	A	2.75	217 t	0.2	0.1 t	0.054	0.000	0.000	0.054	0.31	0.4	4.5	40	15	10	15	37
77	A	1.60	429 t	0.4	0.1 t	0.052	0.000	0.000	0.052	0.01 t	0.2	3.6	16	8	6	7	20
82	A	1.70	0 t	0.2	0.1 t	0.000	0.035	0.000	0.035	0.00 t	0.2	6.2	23	15	12	9	27
81	A	1.06	47 t	0.2	0.0 t	0.000	0.031	0.000	0.031	0.00 t	0.2	4.6	26	13	9	10	31
76	A	1.83	434 t	0.1 t	0.0 t	0.145	0.000	0.000	0.145	0.01 t	0.2	14.0	45	38	31	7	53
80	A	3.10	913 t	0.7	0.1 t	0.098	0.000	0.000	0.098	0.00 t	0.2	8.5	38	30	17	16	46
86	A	1.56	222 t	0.2	0.0 t	0.038	0.000	0.000	0.038	0.11	0.2	7.8	24	14	15	8	29
87	A	2.30	499 t	0.3	0.0 t	0.033	0.000	0.000	0.033	0.10	0.2	9.8	35	16	20	9	40
85	A	3.14	95 t	0.5	0.0 t	0.049	0.000	0.000	0.049	0.09	0.2	11.0	35	18	22	9	41
91	A	4.63	0 t	0.4	0.3 t	0.055	0.000	0.000	0.055	0.13	0.2	10.0	34	17	20	14	43
92	A	1.55	0 t	0.1	0.1 t	0.047	0.000	0.000	0.047	0.06	0.2	5.8	19	11	12	7	22
93	A	3.83	0 t	0.1 t	0.0 t	0.044	0.041	0.000	0.085	0.16	0.2	20.0	64	35	44	19	74
83	A	1.96	0 t	0.2	0.1 t	0.039	0.000	0.000	0.039	0.13	0.2	4.3	22	10	8	7	24
94	A	2.57	951	0.4	0.0 t	0.056	0.041	0.000	0.097	0.05	0.2	20.0	70	41	44	20	74
63	A	3.03	236 t	0.2	0.1 t	0.000	2.240	1.066	3.306	0.02 t	0.2	3.0	15	12	8	10	40
64	A	2.91	537 t	0.1 t	0.3 t	0.000	0.061	0.000	0.061	0.04	0.2	6.2	36	22	14	17	60
69	A	1.82	191 t	0.1 t	0.0 t	0.000	0.050	0.000	0.050	0.02	0.2	3.7	23	12	8	11	32
73	A	1.56	211 t	0.2	0.1 t	0.125	0.000	0.000	0.125	0.00 t	0.2	4.0	29	11	7	8	30
75	C	1.75	442 t	0.1	0.2 t	0.123	0.000	0.000	0.123	0.01 t	0.4	2.8	16	10	5	9	30
78	[illegible]	3.11	619 t	1.3	0.0 t	0.041	000	0.000	0.041	0.02 t	0.2	7.6	40	21	15	18	57

cont. National Fisheries Center - Great Lakes
Ann Arbor MI 3139941331

Results in mg/kg

STA NO.	SIOC	VOLATILE SOLIDS	OIL	PHENOL	CYANIDE	PCB 1248	PCB 1254	PCB 1260	TOTAL PCB	Hg	Cd	Co	Cr	Cu	Ni	Pb	Zn
79	C	3.76	573 t	0.3	0.0 t	0.077	0.000	0.000	0.077	0.02 t	0.2	6.9	34	22	15	20	61
83	A	3.26	0 t	0.4	0.0 t	0.000	0.045	0.000	0.045	0.09	0.2	7.5	42	24	16	18	59
84	C	2.35	0 t	0.1 t	0.1 t	0.000	0.043	0.000	0.043	0.06	0.2	14.0	54	30	33	13	59
90	A	3.62	0 t	0.1	0.0 t	0.057	0.050	0.000	0.107	0.08	0.2	15.0	63	31	34	20	63
89	A	2.89	0 t	0.4	0.1 t	0.052	0.046	0.000	0.098	0.14	0.2	8.0	50	21	17	16	50
96	A	3.75	0 t	0.1 t	0.1 t	0.000	0.041	0.000	0.041	0.06	0.2	9.2	49	26	21	20	64
95	A	1.25	137 t	0.0 t	0.1 t	0.029	0.000	0.000	0.029	0.04	0.2	7.6	28	18	15	10	31
97	A	2.75	0 t	0.1 t	0.7 t	0.000	0.030	0.000	0.030	0.10	0.2	8.6	46	22	18	17	51
98	A	2.96	369 t	0.1 t	0.1 t	0.000	0.029	0.000	0.029	0.08	0.2	7.9	39	26	18	22	57
99	A	2.05	0 t	0.1 t	0.0 t	0.000	0.035	0.000	0.035	0.06	0.2	11.0	35	25	22	15	45
100	A	3.31	235 t	0.1 t	0.1 t	0.000	0.037	0.000	0.037	0.04	0.2	10.0	51	25	20	21	57
101	A	4.09	343 t	0.0 t	0.0 t	0.000	0.036	0.000	0.036	0.06	0.2	11.0	48	29	24	23	62
102	A	4.42	364 t	0.0 t	0.3 t	0.000	0.035	0.000	0.035	0.04 t	0.2	12.0	55	28	25	19	73
103	A	4.32	310 t	0.1 t	0.1 t	0.000	0.031	0.000	0.031	0.09	0.2	11.0	50	20	24	19	70
104	C	1.22	122 t	0.0 t	0.0 t	0.035	0.000	0.000	0.035	0.03	0.2	2.8	9	6	6	7	16
105	A	1.58	0 t	0.0 t	0.1 t	0.035	0.000	0.000	0.035	0.00 t	0.2	6.1	20	14	14	7	26
106	A	2.83	88 t	0.8	0.0 t	0.036	0.000	0.000	0.036	0.02	0.2	7.2	27	17	16	10	39
107	C	3.06	0 t	0.2	0.0 t	0.000	0.031	0.000	0.031	0.10	0.2	8.8	41	22	20	19	57
108	A	1.95	47 t	0.1 t	0.1 t	0.000	0.025	0.000	0.025	0.01 t	0.2	6.5	21	10	14	7	29
109	A	4.37	29 t	0.1 t	0.0 t	0.000	0.040	0.000	0.040	0.02 t	0.2	13.0	56	30	29	25	82
110	A	3.31	146 t	0.1 t	0.0 t	0.000	0.020	0.000	0.020	0.02 t	0.2	9.6	45	21	22	13	54
111	A	4.38	0 t	0.2 t	0.2 t	0.000	0.041	0.000	0.011	0.03	0.2	14.0	60	42	26	37	86
112	C	3.90	144 t	0.2	0.2 t	0.000	0.029	0.000	0.029	0.03	0.3	8.1	34	24	20	20	54
113	A	0.64	273 t	0.0 t	0.2 t	0.024	0.000	0.000	0.024	0.03	0.2	1.1	4	2	3	7	6
114	A	4.74	410 t	0.1 t	0.1 t	0.000	0.047	0.000	0.047	0.11	0.2	12.0	54	30	27	20	80
115	A	3.91	1066	0.1 t	0.1 t	0.000	0.052	0.000	0.052	0.01	0.2	11.0	51	27	26	22	79
116	A	4.85	1129	0.0 t	0.2 t	0.000	0.045	0.000	0.045	0.09	0.3	12.0	60	33	29	26	89
117	A	4.12	1013 t	0.1 t	0.4 t	0.000	0.045	0.000	0.045	0.07	0.2	13.0	68	31	29	24	86
118	A	3.19	438 t	0.2	0.2 t	0.000	0.031	0.000	0.031	0.08	0.2	10.0	47	24	23	23	66
119	A	5.00	1250 t	0.3	0.1 t	0.000	0.039	0.000	0.039	0.12	0.2	14.0	63	34	36	29	98
120	A	4.79	744 t	0.2 t	0.2 t	0.000	0.032	0.000	0.032	0.10	0.2	15.0	64	35	38	35	110
121	A	1.94	454 t	0.1	0.3 t	0.000	0.035	0.000	0.035	0.04	0.2	6.1	29	14	14	10	40
122	A	4.17	424 t	0.1 t	2.5	0.000	0.031	0.000	0.031	0.09	0.2	15.0	67	33	33	27	97
123	A	4.58	266 t	0.1 t	0.1 t	0.000	0.034	0.000	0.034	0.10	0.2	11.0	48	30	27	30	79
124	A	4.47	505 t	0.1 t	0.1 t	0.000	0.036	0.000	0.036	0.09	0.2	15.0	63	35	37	38	110
125	A	1.24	150 t	0.1 t	0.1 t	0.000	0.023	0.000	0.023	0.02	0.2	9.0	11	7	7	10	21

Table 5 Organic contaminants in sediment samples collected from the St. Mary's River during 1985 by MOE.

STN #	DISTANCE FROM U.S. SHORE (m)	DIELDRIN	METHOXYCHLOR	ENDRIN	ENDOSULFAN II	ENDOSULFAN I	HEPT. EPOXIDE	TOTAL PCB's	p.p-DDE
5	1680	.	.	.	.	.	.	.	.
6	2130	16.17	79.83	14.00	15.67	28.00	4.83	.	.
7	600	10.00	.	.	.	.	.	.	.
9	15	16.00	.	.	.	.	.	250.00	6.00
9	840	16.00	.	.	.	.	.	250.00	6.00
27	40	10.00	.	.	.	.	.	.	.
27	950	15.00	5.00	.	10.00	15.00	.	.	2.00
33	200	.	.	4.00	.	.	.	.	.
33	300	12.00	.	4.00	6.00	.	.	30.00	.
34	60	13.50	.	.	.	12.00	.	22.50	1.50
34	210	43.00	.	.	.	.	.	.	.
34	370	54.00	.	.	.	12.00	.	30.00	2.00
34	520	.	.	.	.	.	.	32.50	2.50
34	640	.	.	.	.	.	.	40.00	4.00
38	280	26.00	.	.	.	11.00	.	40.00	3.00
38	350	.	.	.	.	.	.	.	.
38	420	.	.	.	.	.	.	.	.
38	490	.	.	.	.	1.00	.	.	.
38	560	.	.	.	.	.	.	.	.
40	1300	4.00	.	4.00	.	.	.	.	2.00
40	1860	4.00	.	4.00	.	.	.	.	.
40	2450	.	.	4.00	.	.	.	.	.
40	2500	3.00	.	4.00	.	.	.	.	.
80	250	16.00	.	.	.	.	.	.	.
81	900								
82	1500	93.00	.	.	.	.	.	.	.
83	1740	52.00	.	.	.	.	.	.	.
84	2300	11.00	.	.	.	.	.	.	.
85	120	20.00	16.00	.	.	.	.	.	.
86	830	55.83	.	.	.	.	.	.	1.50
87	825	25.00	.	5.00	.	.	3.00	65.00	3.00
88	1430	104.00	.	.	.	.	.	.	.
89	2130	37.00	.	.	.	.	2.00	.	.
90	4150	87.00	.	.	.	.	.	.	.
91	5680	30.00	.	.	.	.	.	.	.
92	5680	8.17	.	.	.	.	.	.	.
93	2480	.	.	.	.	.	.	.	.
94	350	.	.	.	.	.	.	.	.
95	400	.	.	.	.	.	.	.	.
96	3110	.	.	.	.	.	.	.	.
97	1680	.	.	.	.	.	.	.	.
98	3850	.	.	.	.	.	.	30.00	.
99	4580	.	.	.	.	.	.	.	.
100	2740	.	.	.	.	.	.	.	.
101	530	.	.	.	.	.	.	.	.
102	1250	.	.	.	.	.	.	40.00	2.00
103	4280	.	.	.	.	.	.	.	.
104	2420	.	.	.	.	.	.	.	.
105	2850	.	.	.	.	.	.	.	.
106	450	.	.	.	.	.	.	.	.
107	1180	71.00	145.00	.	.	5.00	.	60.00	2.00
108	625	15.00	.	.	.	.	.	.	.
109	1800	39.00	.	.	.	.	.	.	.
110	2360	35.00	.	.	.	.	.	.	.
111	3200	32.00	.	.	.	.	.	.	.
112	100	6.00	.	.	.	.	.	.	.
113	1180	37.50	.	.	.	.	.	.	.
114	2030	3.00	.	.	.	.	.	.	.
115	0	23.00	125.00	14.00	21.00	39.00	8.50	35.00	1.50
116	0	.	.	.	.	.	.	.	.
117	0	8.00	.	4.00	.	.	.	.	.
118	1510	.	.	4.00	.	.	.	.	.
119	0	6.00	93.00	.	10.00	18.00	2.00	.	.
120	1480	7.00	.	.	.	.	.	.	.
121	1510	.	.	.	.	.	.	.	.
122	1450	.	.	4.00	.	.	.	.	.
123	1870	4.00	.	4.00	.	.	.	.	.
124	2400	3.00	.	4.00	.	.	.	.	.
125	900	.	.	4.00	.	.	.	.	.
126	1600	3.00	.	4.00	.	.	.	.	.
127	1750	.	.	4.00	.	.	.	.	.
15001	0	39.00	.	.	.	.	2.00	.	.
15003	0	9.00	.	.	.	.	.	.	.
15004	0	39.00	.	.	.	.	.	.	.
15005	0	17.00	.	.	.	.	.	.	.
15006	0	13.00	.	.	.	.	.	110.00	3.00
15007	0	.	.	.	.	.	.	.	.
15008	0	.	.	.	.	.	.	.	.

"." - NOT DETECTED

- - Metal contaminants in sediment samples collected from the St. Mary's River during 1985 by MOE

STN #	DISTANCE FROM U.S. SHORE (m)	AlUT	AsUT	CdUT	CoUT	CrUT	CuUT	FeUT	HgUT	MnUT	NiUT	PbUT	SeUT	ZnUT
5	1680	11000.00	8.03	0.66	9.10	48.00	35.00	23000.00	0.05	780.00	17.00	26.00	2.44	100.00
6	2130	10250.00	17.55	0.20	3.33	43.67	37.83	53166.67	0.13	1023.33	18.17	91.17	1.77	520.00
7	600	4100.00	77.40	0.20	13.00	140.00	100.00	250000.00	0.03	2100.00	58.00	52.00	0.03	76.00
9	15	3900.00	1.56	0.20	2.90	55.00	22.00	6300.00	0.01	60.00	4.20	160.00	0.10	37.00
9	840	11000.00	20.10	0.84	2.00	91.00	100.00	68000.00	0.38	760.00	26.00	140.00	1.55	370.00
27	40	2800.00	1.06	0.20	2.80	44.00	12.00	5100.00	0.03	54.00	2.70	11.00	0.10	25.00
27	950	5400.00	9.87	0.20	5.20	85.00	41.00	35000.00	0.20	330.00	13.00	40.00	0.51	130.00
33	200	3600.00	2.51	0.20	4.30	10.00	6.60	10000.00	0.01	120.00	6.00	3.50	0.03	20.00
33	300	7600.00	30.00	0.20	2.00	41.00	21.00	64000.00	0.07	2400.00	12.00	91.00	0.52	1200.00
34	60	10500.40	11.37	0.62	8.15	54.00	51.50	31000.00	0.16	340.00	20.50	81.00	1.72	205.00
34	210	4900.00	1.78	0.20	5.10	8.80	12.00	9900.00	0.02	88.00	4.80	6.40	0.03	34.00
34	370	3400.00	4.43	0.43	5.10	30.00	26.00	18000.00	0.07	170.00	8.90	30.00	0.51	140.00
34	520	6150.15	4.55	0.48	6.60	33.00	46.50	26000.00	0.23	215.00	10.50	51.50	0.97	150.00
34	640	6300.00	4.67	0.45	6.80	36.00	35.00	21000.00	0.13	220.00	12.00	43.00	0.64	170.00
38	280	10000.00	12.66	0.65	3.30	65.00	66.00	51000.00	0.15	550.00	21.00	57.00	1.16	200.00
38	350	3900.00	2.61	0.20	3.50	9.40	10.00	9300.00	0.01	130.00	3.60	9.40	0.10	38.00
38	420	1600.00	1.42	0.20	2.00	10.00	4.40	4800.00	0.02	46.00	2.00	4.80	0.03	17.00
38	490	1100.00	1.49	0.20	2.00	3.60	3.30	3900.00	0.02	40.00	2.00	4.90	0.03	14.00
38	560	2600.00	2.38	0.20	3.10	9.20	9.00	7100.00	0.05	73.00	4.60	8.20	0.51	36.00
40	1300	2100.00	2.20	0.20	2.70	5.70	6.50	4900.00	0.01	56.00	3.10	5.70	0.17	16.00
40	1860	4600.00	2.51	0.20	4.50	12.00	11.00	9400.00	0.01	110.00	6.40	8.70	0.17	26.00
40	2450	3100.00	2.28	0.20	3.30	7.90	5.60	6600.00	0.01	170.00	3.80	4.10	0.05	27.00
40	2500	3800.00	2.42	0.20	4.00	11.00	6.60	7500.00	0.01	210.00	6.10	5.30	0.17	30.00
80	250	12000.00	3.10	0.20	9.00	34.00	23.00	16000.00	0.03	290.00	14.00	13.00	1.26	63.00
81	900	6400.00	2.56	0.20	6.00	22.00	18.00	13000.00	0.02	210.00	8.00	14.00	0.82	58.00
82	1500	6600.00	3.17	0.20	6.00	21.00	14.00	11000.00	0.02	220.00	8.00	12.00	0.50	51.00
83	1740	4500.00	2.30	0.20	4.00	15.00	13.00	9000.00	0.02	120.00	5.00	11.00	0.93	43.00
84	2300	8600.00	4.32	0.30	8.00	28.00	30.00	15000.00	0.06	240.00	10.00	21.00	4.27	81.00
85	120	7050.00	7.91	0.50	7.00	51.50	48.00	31500.00	0.09	320.00	14.50	41.00	2.60	125.00
86	830	12666.67	5.00	0.62	10.67	46.00	45.33	25666.67	0.08	331.67	18.67	26.67	3.57	125.00
87	825	12000.00	10.21	1.10	8.00	61.00	69.00	39000.00	0.19	480.00	23.00	54.00	3.98	220.00
88	1430	9100.00	4.14	0.60	8.00	40.00	32.00	19000.00	0.09	220.00	14.00	28.00	3.91	120.00
89	2130	12000.00	7.26	0.80	10.00	47.00	43.00	25000.00	0.11	320.00	19.00	41.00	5.24	180.00
90	4150	6000.00	2.91	0.20	6.00	24.00	13.00	15000.00	0.02	230.00	8.00	9.00	1.04	38.00
91	5680	8100.00	3.17	0.40	7.00	27.50	21.50	13500.00	0.04	220.00	11.00	15.00	2.39	69.00
92	5680	13833.33	7.27	0.68	10.00	49.17	40.67	27666.67	0.11	385.00	19.17	43.67	3.74	161.67
93	2480	17000.00	12.50	0.93	10.00	51.00	51.00	36000.00	0.16	640.00	24.00	60.00	6.48	230.00
94	350	6300.00	1.96	0.20	5.20	15.00	12.00	10000.00	0.01	160.00	7.10	4.90	0.24	38.00
95	400	12000.00	7.64	0.54	9.20	32.00	30.00	23000.00	0.08	420.00	15.00	28.00	1.38	120.00
96	3110	16000.00	9.45	0.82	9.60	49.00	48.00	36000.00	0.16	500.00	23.00	52.00	1.55	210.00
97	1680	18000.00	14.82	1.10	9.40	55.00	58.00	42000.00	0.21	640.00	24.00	68.00	3.20	200.00

STN #	DISTANCE FROM U.S. SHORE (m)	AlUT	AsUT	CdUT	CoUT	CrUT	CuUT	FeUT	HgUT	MnUT	NiUT	PbUT	SeUT	ZnUT
98	3850	14000.00	9.35	0.90	8.70	51.00	50.00	35000.00	0.17	430.00	21.00	52.00	1.29	210.00
99	4580	4000.00	1.64	0.20	4.70	14.00	7.30	17000.00	0.01	130.00	3.70	3.80	0.37	21.00
100	2740	15000.00	8.44	0.76	9.30	49.00	53.00	36000.00	0.12	450.00	22.00	41.00	1.68	180.00
101	530	12000.00	7.77	0.42	9.60	34.00	32.00	23000.00	0.09	410.00	15.00	30.00	0.51	120.00
102	1250	18000.00	10.30	0.76	11.00	53.00	59.00	38000.00	0.16	490.00	25.00	49.00	1.29	210.00
103	4280	3900.00	1.35	0.20	3.80	11.00	8.30	8600.00	0.01	100.00	3.60	8.50	0.10	33.00
104	2420	12000.00	4.35	0.36	10.00	37.00	35.00	25000.00	0.06	300.00	16.00	22.00	0.24	100.00
105	2850	18000.00	7.77	0.58	11.00	50.00	45.00	32000.00	0.11	450.00	24.00	38.00	1.68	170.00
106	450	11000.00	2.46	0.21	9.30	30.00	28.00	19000.00	0.04	240.00	14.00	12.00	0.24	63.00
107	1180	7300.00	13.43	0.20	4.50	75.00	52.00	43000.00	0.16	510.00	17.00	50.00	0.51	170.00
108	625	2700.00	1.42	0.20	2.90	12.00	6.50	5400.00	0.01	89.00	2.00	3.20	0.24	16.00
109	1800	3900.00	1.42	0.20	3.80	22.00	8.50	6600.00	0.02	81.00	5.30	5.30	0.24	17.00
110	2360	3000.00	1.35	0.20	2.90	10.00	6.20	6200.00	0.01	7000.00	3.20	2.80	0.03	15.00
111	3200	2900.00	1.86	0.20	3.30	9.30	6.70	5500.00	0.01	70.00	4.20	3.70	0.03	14.00
112	100	4300.00	1.35	0.20	4.00	17.00	8.50	6100.00	0.01	92.00	5.50	5.30	0.03	18.00
113	1180	6700.00	4.51	0.20	6.40	34.00	19.50	14500.00	0.04	215.00	10.60	19.50	0.17	54.50
114	2030	13000.00	4.92	0.20	11.00	49.00	39.00	21000.00	0.06	300.00	21.00	29.00	0.77	110.00
115	0	7900.00	20.05	0.20	5.70	55.00	50.00	44000.00	0.11	885.00	20.50	52.50	1.89	170.00
116	0	30000.00	3.81	0.20	17.00	60.00	39.00	32000.00	0.01	530.00	35.00	12.00	1.10	65.00
117	0	8700.00	43.90	0.20	2.00	44.00	38.00	97000.00	0.13	3700.00	15.00	250.00	0.98	660.00
118	1510	3200.00	19.00	0.20	2.00	31.00	20.00	150000.00	0.02	2200.00	7.40	30.00	0.03	320.00
119	0	8100.00	15.60	0.20	2.00	38.00	24.00	65000.00	0.11	1300.00	13.00	34.00	0.52	260.00
120	1480	4000.00	2.97	0.20	4.50	12.00	4.80	11000.00	0.06	140.00	7.00	13.00	0.03	36.00
121	1510	3200.00	5.84	0.20	4.10	59.00	5.60	14000.00	0.02	2100.00	11.00	8.20	1.67	32.00
122	1450	11000.00	5.50	0.20	8.90	36.00	34.00	22000.00	0.06	480.00	16.00	22.00	0.87	100.00
123	1870	10000.00	1.87	0.20	9.20	23.00	18.00	15000.00	0.01	210.00	14.00	5.10	0.03	30.00
124	2400	2400.00	1.04	0.20	2.70	11.00	2.70	4800.00	0.01	69.00	6.60	2.00	0.05	21.00
125	900	3400.00	2.42	0.20	3.90	11.00	11.00	8300.00	0.01	85.00	5.90	10.00	0.17	24.00
126	1600	3300.00	2.05	0.20	3.50	8.50	6.90	6000.00	0.01	75.00	4.60	5.20	0.03	17.00
127	1750	8900.00	19.00	0.20	3.60	43.00	32.00	51000.00	0.12	990.00	19.00	73.00	0.98	450.00
001	0	5000.00	8.50	0.20	6.30	28.00	24.00	22000.00	0.02	470.00	11.00	16.00	0.11	83.00
003	0	5900.00	0.88	0.20	6.30	15.00	7.70	12000.00	0.01	140.00	10.00	2.00	0.11	44.00
004	0	5600.00	0.61	0.20	5.90	11.00	8.60	10000.00	0.01	190.00	8.40	2.40	0.11	81.00
005	0	7300.00	0.98	0.20	8.00	21.00	12.00	16000.00	0.01	220.00	13.00	3.00	0.03	48.00
006	0	8700.00	23.50	0.20	5.30	130.00	69.00	44000.00	0.07	760.00	22.00	76.00	0.03	120.00
7	0	2400.00	0.77	0.20	2.70	6.40	4.20	4800.00	0.01	56.00	3.60	2.00	0.03	12.00
8	0	6300.00	1.78	0.20	6.90	12.00	12.00	13000.00	0.01	140.00	7.90	2.10	0.03	25.00

UT - Unfiltered Total

AlUT - Aluminum
AsUT - Arsenic
CdUT - Cadmium
CoUT - Cobalt
CrUT - Chromium
CuUT - Copper
FeUT - Iron
HgUT - Mercury
MnUT - Manganese
NiUT - Nickel
PbUT - Lead
SeUT - Selenium
ZnUT - Zinc

TABLE 7
ORGANIC CONTAMINANTS ON THE SAINT MARY'S RIVER 1984
US EPA/NATIONAL PROGRAM OFFICE
230 SOUTH DEARBORN STREET
CHICAGO, ILLINOIS 60604

VALUES IN mg/kg

STA	LATITUDE	LONGITUDE	LOCATION	%TOTAL SOLIDS	VOLATILE SOLIDS	NH4	OIL	TKN	PCB 1254	PHOS	CYANIDE
CCT-33	46-24-47	84-35-11	LITTLE WAISKA CREEK	70.2	2.2	34	650	300		250	0.1
CCT-34A	46-24-37	84-34-17	WAISKA RIVER UPSTREAM	60.7	3.8	46	650	1100		510	0.2
CCT-35	46-29-30	84-24- 5	SEYMOUR CREEK	66.4	1.1	10	650	240	0.030	200	0.2
CCT-36	46-29-42	84-22-22	ASHMUN CREEK	65.4	3.1	71	1060	560	0.030	330	0.2
CCT-37	46-28-40	84-18-16	MISSION CREEK	69.7	1.9	37	650	640	0.030	420	0.2
CCT-38	46-27-29	84-17-12	FRECHETTE CREEK	77.6	0.9	19	650 <	150		440	0.2 T
CCT-39	46-26-42	84-16-27	ERMATINGER CREEK	71.8	1.7	60	650	390		420	0.2
CCT-40	46-28-20	84-15-34	BEAVER DAM CREEK BAIE deW	26.7	10.1	59	913	1200	0.049	150	0.5
CCT-41	46-30-52	84-14-23	McFARLAND CREEK	62.4	2.9	30	650 <	430		530	0.2 T
CCT-44	46-27-16	84-11-12	ROCL BOTTOM CRK-E SUGAR I	62.9	3.0	30	650 <	99	0.054	520	0.2
CCT-46	46-23-43	84-15-36	HURSLEY CREEK	75.6	0.7	9	650 <	99		130	0.3 T
CCT-47	46-23-24	84-15-30	SAILOR'S CREEK	65.5	2.2	43	650 <	320	0.030	380	0.1 T
CCT-48A	46-19-17	84-13-43	CHARLOTTE RIVER UP STREAM	59.0	2.7	66	650 <	560		520	0.2 T
CCT-49B	46-13-24	84-15-38	MUNUSCONG RIVER	59.6	3.7	53	650 <	530		490	0.2 T
CCT-50A	46-12-54	84-15-42	MUNUSCONG RIVER UPSTREAM	59.0	2.7	53	650 <	450		520	0.2 T
CCT-51	46- 2-19	83-40- 3	POTOGANNISSING RIVER	56.9	1.5	47	650 <	240		460	1.5 T
CCT-51D	46- 2-19	83-39-57	POTOGANNISSING RIVER	65.9	1.5	36	650 <	230		500	1.5 T
CCT-52A	46- 9-27	84- 6-43	GOGMAIN RIVER UPSTREAM	59.3	2.9	36	650 <	230		500	1.5 T
CCT-54	46-3-11	84- 1-32	CARLTON CREEK	77.9	0.9	17	650 <	200		210	0.2 T

TABLE 8
INORGANIC SEDIMENT CONTAMINANTS ON THE SAINT MARY'S RIVER 1984
US EPA NATIONAL PROGRAM OFFICE
230 SOUTH DEARBORN STREET
CHICAGO, ILLINOIS 60604 VALUE mg/kg

STA	Hg	As	Cd	Co	Cr	Cu	Ni	Pb	Zn	Fe
CCT-33		0.6	0.2	3	9	6	6	7	16	4800
CCT-34A		1.1	0.2	5	16	8	10	9	41	8900
CCT-35			0.2	2	4	3	3	7	14	3300
CCT-36	0 T	1.1	0.2	3	16	10	6	13	44	5500
CCT-37	0 T	0.5	0.2	3	9	6	5	10	34	4500
CCT-38	0 T	0.6	0.2	3	11	7	8	7	12	5800
CCT-39	0 T	0.7	0.2	3	11	7	6	11	27	5000
CCT-40	0 T	1.6	0.2 T	5	16	11	12	7 T	28	8000
CCT-41	0 T	0.9	0.2 T	11	38	21	25	11	43	19000
CCT-44	0 T	2.1	0.2	19	69	44	45	21	74	33000
CCT-46	0 T	0.2	0.2 T	2			3	7 T		2000
CCT-47	0 T	1.5	0.2 T	11	45	21	26	7 T	47	23000
CCT-48A	0	1.3	0.3	0	25	12	15	7 T	47	16000
CCT-49B	0	1.4	0.2	8	23	13	15	7 T	44	13000
CCT-50A	0 T	1.1	0.3	8	25	14	18	7 T	40	14000
CCT-51	0	2.3	0.2 T	16	63	32	40	7 T	72	31000
CCT-51D			0.2 T	13	51	25	33	7 T	59	25000
CCT-52A	0		0.2 T	13	51	25	33	7 T	59	25000
CCT-54	0 T	0.4 T	0.2 T	2	5	2	3	7 T	9	3000

Appendix 6.3

The Provincial Sediment Quality Guidelines, March 1991 (Draft)

THE PROVINCIAL SEDIMENT QUALITY GUIDELINES

DRAFT

DRAFT

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March 1991

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3.2 SPECIFIC APPLICATIONS

3.2.1 Placement of Fill Directly into a Watercourse

Fill refers to any type of solid material, other than those defined as inert (i.e., chemically clean) under MOE's Waste Management Guidelines described in Regulation 309 of the Environmental Protection Act, used in shoreline or nearshore development programs generally referred to as lakefilling.

As a minimum, chemical analyses shall be carried out for all parameters in Tables 1 and 2 unless specific agreement to the contrary is obtained from the MOE.

Fill material equal to, or better than, the No-Effect Level Guidelines can be used without restriction in a watercourse.

The conditions governing fill that exceed the No-Effect Level are outlined in MOE's guidelines on lakefilling.

3.2.2 Sediment Monitoring Programs

When sediment quality in an area consistently exceeds the Lowest Effect Level Guideline, subject to the conditions in 3.1.1.(g) above, that area shall be designated an area of potential concern, and the actions outlined below shall apply. The sediment evaluation procedure is shown in detail in Figure 2. Sediments that are below the Lowest Effect Level should pose no significant threat to the majority of benthic organisms.

3.2.3 Areas of Potential Concern and IJC 'Areas of Concern'

In areas where contaminants in sediment are at or above the Lowest Effect Level, immediate steps should be taken to *control all point and non-point contaminant sources* to the area. Consideration will be given to the provisions governing areas of high mineralization and atmospheric deposition as outlined in section 3.1.1.(g) and (h).

In areas where contaminants in sediment are at or above the Severe Effect Level, the sediment is deemed to be highly contaminated and measures in addition to source control may be required to clean up the sediment. Such measures should be determined on the basis of the biological tests outlined below. If the sediment fails either of the tests, *in-situ* remedial action is warranted. If the sediment passes both tests, efforts should be directed towards point and non-point source control. *In-situ* clean-up must not be a substitute for source control. The sediment evaluation procedure is outlined in detail in Figure 2.

Biological Tests

The following lethality test, or an equivalent test approved by MOE will be carried out to determine the need for *in-situ* sediment remedial action. Details on the following tests are provided in Lomas & Krantzberg (1988).

Sediment Bioassay Protocol

The experiments are run as static beaker tests, using two types of aquatic biota: 3-4 month old fathead minnows, *Pimephales promelas* (to assess effects of contaminated sediment on water column organisms) and 2nd year nymphs of the burrowing mayfly, *Hexagenia limbata* (to assess effects of contaminated sediment on a sediment-dwelling organism). The organisms are placed in jars (2 litre) with dechlorinated water and sediment (4:1 ratio) for a 10-day exposure period. At the end of the experiment, percent mortality is calculated.

Selection of Controls

Controls are very important and necessary for proper interpretation of bioassay results. Two types of control sediments are selected for the Sediment Bioassay Protocol and these are:

- Sediment where test organisms were collected from or cultured in.
- Control site from study location, upstream or removed from the pollution sources being assessed but as similar as possible in composition.

Data Interpretation

Data interpretation involves comparing bioassay results from test sediments to results from:

- replicate test sediments to address variability among replicates

- control sediments that organisms were collected from or cultured in

- upstream control sediments or sediments removed from pollution sources being assessed.

Statistically significant ($P < 0.05$) differences between test control sediments for the various endpoints indicate that test sediments have negatively impacted the biota. Control mortality is monitored and must not exceed 10% for the validation of test results.

3.2.4 Dredged Material Disposal

Dredged material refers to any material removed from the bottom of a watercourse as a result of capital or maintenance dredging, remedial action or spills clean-up. The conditions outlined below relate only to material being considered for disposal in open water and does not include material to be placed within Confined Disposal Facilities (CDFs). Analyses will be performed for all parameters listed in Tables 1 and 2, unless previous data suggest the absence of certain parameters.

A. Disposal in Areas With Sediment Quality Equal to or Better Than the No-Effect Level Guidelines.

The dredged material to be disposed of must not exceed the No-Effect Level Guidelines.

B. Disposal in Areas With Sediment Quality Exceeding the No-Effect Level Guidelines.

The dredged material to be disposed of in such areas must be below the Lowest Effect Level Guidelines, subject to the conditions described in 3.1.1.(g). In addition to meeting the chemical quality, the general provisions outlined below must also be met. Detailed application of these guidelines is shown in Figure 3.

General Provisions Governing Open-Water Disposal of Dredged Material.
(for details refer to IJC 1983)

Open Water Disposal Sites Should Be Located So As To Avoid Adverse Impacts On:

1. Commerce and transportation, including commercial shipping, commercial fishing, pipeline and cable crossings and mineral and aggregate extraction.

2. Water intakes and outfalls.

3. Recreational uses and aesthetic values of the area.

4. Bottom topography so as not to adversely impact water circulation, current patterns, water level fluctuations, temperature regime, erosion and accretion patterns, and wave climate.

5. Sites of natural, cultural, archaeological, historical, and research significance.

6. Sanctuaries and refuges, breeding, spawning, nursery and feeding habitats, and passage areas for biota.

7. Species of special interest such as threatened and endangered species.

In Addition, Open Water Disposal Sites Should:

1. Be compatible with physical and chemical characteristics of the dredged material to the extent practicable.

2. Utilize the smallest practicable disposal area.

3. Use current and past material disposal sites, if these sites meet the proposed guidelines.

4. Be selected to minimize the dispersal, erosion and slumping of the material to affect the smallest practicable part of the waterbody.

3.2.5 Spills Clean-up

In areas where ambient or background sediment levels of the substance(s) spilled are below the No-Effect Level, the clean-up level will, as a minimum, be to the No-Effect Level. If the ambient sediment levels for that watercourse are above the No-Effect Level, then cleanup will be, as a minimum, to the local ambient level. To clean up beyond the ambient level would be of no lasting benefit due to the long-term migration and cycling of sediment within the ecosystem.

SECTION 4

PROTOCOL FOR SETTING SEDIMENT QUALITY GUIDELINES

4.1 RATIONALE FOR SETTING SEDIMENT QUALITY GUIDELINES

In developing guidelines to provide adequate protection for biological resources, the Ministry has attempted to ensure that the methods employed consider the full range of natural processes governing the fate and distribution of contaminants in the natural environment. Since benthic organisms respond to a variety of stress-inducing factors they are, in essence, integrators of all the physical, chemical and biological phenomena being experienced in their environment and these organisms should form the basis of any method used in setting sediment guidelines.

Because individual species may respond differently to stress-inducing factors it is very difficult to study a specific organism (eg. a sensitive species) with the hope of developing guidelines that will protect the rest of the community. Sensitivity to chemical contaminants has not been fully evaluated for different benthic organisms and most sediment bioassay work has been concerned mainly with a few selected species (eg. the mayfly *Hexagenia*). While the mayfly has traditionally been used as a "sensitive" indicator organism for factors such as low dissolved oxygen, its sensitivity relative to other benthic organisms has not been clearly established for chemical contaminants. Therefore, in developing SQGs, the Ministry has not relied on single-species data.

Similarly, a method that relies heavily on those species that are known to be extremely tolerant of contaminants in sediment cannot result in guidelines that will adequately protect less tolerant members of the aquatic community. It has been demonstrated that some populations can adapt to varying levels of environmental contamination with increasing tolerance to these contaminants occurring in succeeding generations. This can present difficulty in laboratory studies of reared populations since these may lack the genetic diversity found in natural populations and responses may not be consistent with those observable under field conditions.

Another concern in relation to placing heavy reliance on laboratory data stems from the fact that in most situations contaminants in sediments exist as mixtures of various substances. Laboratory tests have been geared towards examining the effects of single substances and laboratory data can be difficult to apply to field situations.

In developing the protocol for setting Sediment Quality Guidelines, the ministry considered a number of different approaches developed by state and federal agencies in North America that employed various degrees of biological assessment. The various suggestions for the development of Sediment Quality Guidelines can be summarized in five approaches as possible means of setting sediment quality guidelines. At present, no single approach can adequately account for all the factors that operate in natural sediments and each of the five approaches has positive attributes as well as limitations with regard to the development of biologically based guidelines. The rationale used in setting Sediment Quality Guidelines includes a number of considerations which are detailed below. These considerations provided the basis for selecting the best method or combination of methods for Sediment Quality Development.

1. Sediment Quality Guidelines should consider a range of contaminant concentrations that is wide enough to determine the level at which ecotoxic effects become noticeable. This can be achieved most effectively by looking at a large number of organisms under the widest possible range of contaminant exposure. Only then can the appropriate ecotoxic level be adequately determined. A restricted range may result in the setting of guidelines that are not reflective of actual ecotoxic effects on organisms and as such may be overprotective. This is especially important where the range of effects used may not cover the entire tolerance range of the species in question.

2. SQGs should be based on cause-effect relationships between a specific contaminant and benthic organisms since it is necessary to demonstrate that at a certain concentration a contaminant results in adverse effects on benthic organisms.

3. SQGs should account for contaminant effects in a multi-contaminant medium. Since contaminated sediments usually